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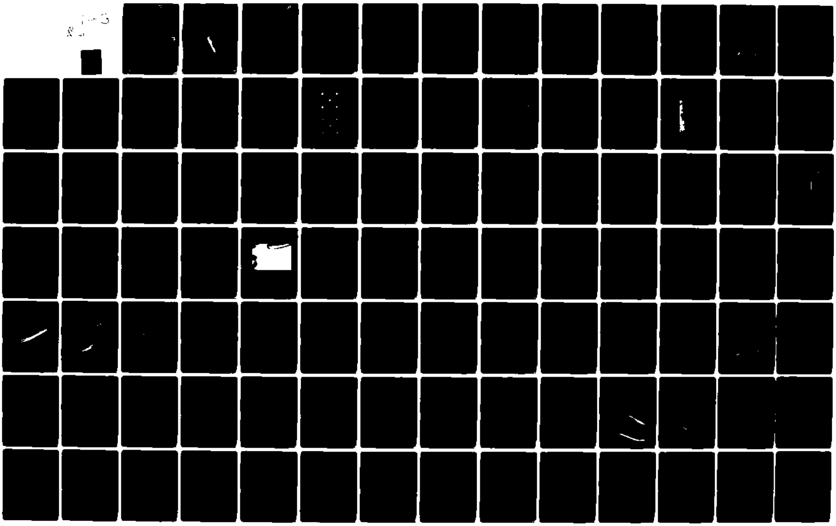

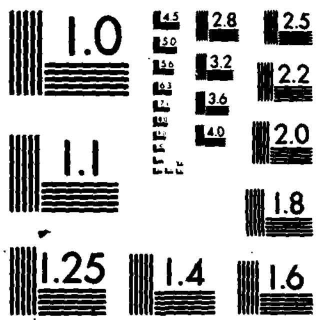
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In order to determine the effects of the continental shelf bathymetry on coastal geomorphology, a series of wave-refraction diagrams were generated for the S. C. coast from Bull Island to the Isle of Palms. REFRAC, a computerized wave-refraction program developed for this study, generates refraction diagrams which delineate the patterns of longshore variation in wave energy. A variety of input wave conditions were used in REFRAC to model the various possible wave conditions existing in nature. The results indicate that the offshore bathymetry does partially control the coastal geomorphology by creating zones of potential erosion and deposit and by influencing the direction of sediment transport

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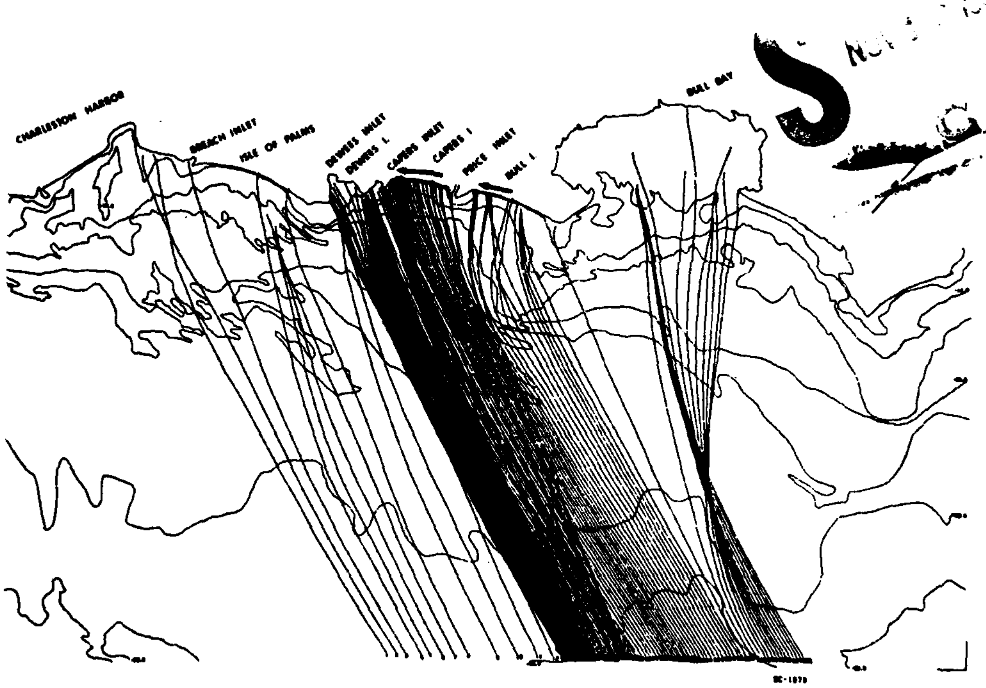
Technical Report No. 17-CRD

Influence of Wave Refraction on Coastal Geomorphology

Bull Island to Isle of Palms, South Carolina

Cary Fico



Coastal Research Division

Department of Geology

University of South Carolina

Columbia, South Carolina 29208

INFLUENCE OF WAVE REFRACTION ON COASTAL GEOMORPHOLOGY -- BULL ISLAND TO ISLE OF PALMS, SOUTH CAROLINA

by

Cary Fico

411049

December, 1978

Technical Report No. 17-CRD
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Columbia, South Carolina

cover diagram: refraction diagram of 10 second period wave from the east

TABLE OF CONTENTS

	Page
ABSTRACT	1
ACKNOWLEDGEMENTS	3
INTRODUCTION	4
LINEAR WAVE THEORY	8
General Description	8
Assumptions and Limitations	9
DATA INPUT	11
South Carolina Wave Climate	11
Bathymetry	17
Shelf Morphology	17
Hydrographic Charts	20
DATA OUTPUT - WAVE-REFRACTION DIAGRAMS	28
Description	28
Discussion	33
CONCLUSIONS	43
REFERENCES	45
APPENDIX I: Refraction Diagrams	I-1
APPENDIX II: REFRAC--User's Guide	
Program Description	II-1
Module Description	II-1
Output Description	II-8
Input Description	II-11
Card Input Formatting	II-11
Digitized Depth Input	II-15
Programming Considerations	II-34
Determination of Input Parameters	II-34
Miscellaneous	II-38
Programs	
REFRAC	II-43
JCL Considerations	II-43
Program Listing, Examples of Input and Output	II-49
TTD (Tape to Disk)	II-97
DIGCOPY (program to list digitized tape)	II-100

LIST OF ILLUSTRATIONS

Figure		Page
1.	Location of study area.	6
2.	Seasonal trends of wind and wave conditions.	13
3.	Frequency of occurrence of sea and swell and their approach direction.	16
4.	Shelf morphology of South Carolina.	19
5.	Relationship of 1st-, 2nd-, and 3rd order diagrams.	22
6.	Accuracy criteria of hydrographic charts.	25
7.	Comparison of coastal geomorphology and zones of converging and diverging wave orthogonal.	35
8.	Model of ebb-tidal delta morphology.	40

LIST OF TABLES

I.	Summary information on hydrographic charts.	23
II.	Explanation of sounding accuracy criteria.	26

ABSTRACT

In order to determine the effects of the continental shelf bathymetry on coastal geomorphology, a series of wave-refraction diagrams were generated for the S. C. coast from Bull Island to the Isle of Palms. Wave rays, as they approach the shore, converge or diverge depending on the uneven offshore bottom topography. Therefore, zones of magnified or reduced wave energy are created from the interaction between waves and the offshore topography. REFRAC, a computerized wave-refraction program developed for this study, generates refraction diagrams which delineate the patterns of longshore variation in wave energy. A variety of input wave conditions were used in REFRAC to model the various possible wave conditions existing in nature. Data input included waves propagated in deep water from the east, southeast and south for several different periods. To improve the accuracy of the refraction diagrams, bathymetric charts of increasing detail near the shore were used in tracing the path of a wave onto the shore. Qualitatively, zones of potential erosion or deposition can be inferred to correspond to converging or diverging wave rays respectively,

The results indicate that the offshore bathymetry does partially control the coastal geomorphology by creating zones of potential erosion and deposition and by influencing the direction of sediment transport. An analysis of the refraction diagrams reveals the following observations. (1) Bull Island and Capers Island, areas of long-term erosion, are located in zones of higher than average wave energy. (2) The southern section of the Isle of Palms has undergone extensive accretion due to its location in a zone of lower

than average wave energy and to a sediment supply from the north. (3) The oblique orientation of Dewees Inlet, as compared to the normal orientation of Price Inlet, results from the increased wave energy noted at Dewees Inlet, especially for a 10-second wave from the east. (4) The large downdrift offset of Dewees Inlet appears to be related to a sudden reduction in the southward directed longshore drift at the Isle of Palms as compared to Dewees and Capers Islands.

Additional information on the sediment transport patterns at the ebb-tidal delta of Price Inlet was gained from the increase in detail of the refraction diagrams for Price Inlet. For waves from the east and southeast, the predominant direction of littoral drift is to the south. Sediment transport reversals to the north were seen on the south side of the inlet. These reversals in transport direction, resulting from refraction around the ebb-tidal delta, are capable of reintroducing sand into the inlet and building up the beach and shoals south of the inlet. On the other hand, shorter period waves from the east, because of their oblique angle of approach to the shoreline, may enhance sediment bypassing around the distal portion of the ebb-tidal delta at Price Inlet.

ACKNOWLEDEMENTS

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I would like to thank Dag Nummedal for his critical review of this text and for his support throughout the study. Jim Crabtree, through his patient help in the computer programming aspects of this project, has stimulated my interest in computer applications. During the several stages of writing, constructive criticism was sought from Bob Ehrlich, Miles Hayes and Bjorn Kjerfve. Burk Scheper and Nanette Muzzy offered many helpful suggestions in preparing the drafts and figures. I especially wish to thank Priscilla Ridgell for typing the final copy of this manuscript.

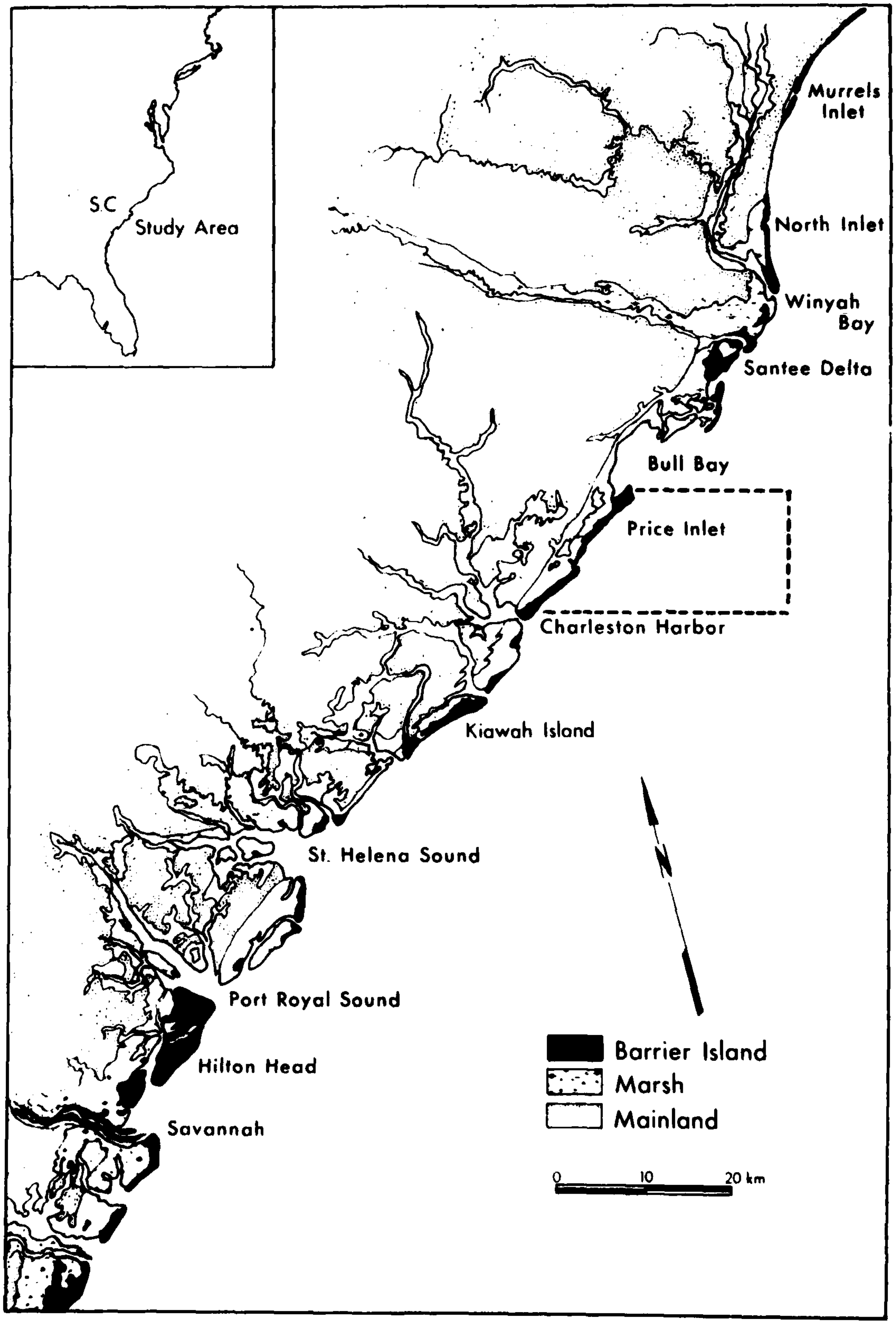
INTRODUCTION

The relationship between the nonuniform wave-energy distribution along a coastline and the coastline's stability, both past and future, is of primary importance in coastal management. A graphical method, based on the principles of refraction, set forth by Snell's Law, is commonly used in displaying wave-energy distribution. These wave-refraction diagrams serve as a useful tool in the interpretation of coastal processes when used in conjunction with field data (Colonell *et al.*, 1973). Goldsmith and others (1970) concluded from refraction computations on Monomy Island that the interaction between incoming waves and variations in the offshore bathymetry may be able to predict changes in the configuration of the shoreline. Fico (1977) depicted areas on the S. C. coast of varying susceptibility to storm damage by refracting waves from several different directions.

This study exemplifies the significance of the offshore bathymetry in modifying the configuration of the S. C. coast from Bull Island to the Isle of Palms (Fig. 1). Through the interaction of waves and the offshore topography, which results in an uneven longshore wave energy distribution, differential rates of deposition or erosion occur along the coast. A series of wave-refraction diagrams were generated to show the correspondence between the variation in the wave-energy distribution and the resulting coastal geomorphology. Furthermore, detailed refraction diagrams of Price Inlet were able to illustrate the effects of the offshore bathymetry on the morphology and sediment transport patterns of an ebb-tidal delta.

A computerized wave refraction procedure, REFRAC, has been implemented on the IBM System 370/168 at the University of South

Figure 1. Location map of the study area.


S.C
Study Area
Murrels Inlet
North Inlet
Winyah Bay
Santee Delta
Bull Bay
Price Inlet
Charleston Harbor
Kiawah Island
St. Helena Sound
Port Royal Sound
Hilton Head
Savannah
Barrier Island
Marsh
Mainland
0
10
20 km

Carolina. Dobson (1967) developed the initial program and based the refraction of incoming waves on linear wave theory. Since he assumed bottom friction to be insignificant, the wave height at any point of interest (usually the breaker zone) is a function of the initial deep water wave height and the refraction and shoaling coefficients at that point. Modifications of this program made by Senter (1972) at the Waterways Experiment Station include the addition of Calcomp plot routines and a window feature which allows wave data generated from a small-scale map to be used as input into a larger-scale map for a more detailed refraction analysis.

REFRAC, including the above modifications, has been further altered in the current study to accept digitized bathymetric input for generation of a depth grid. Previously, areas of interest were overlain by a grid and the depths interpolated from a hydrographic chart at grid points. Next, the interpolated depth data were keypunched onto cards. When using large areas or a series of desired large-scale window plots, this was a very time-consuming process. These tasks are eliminated by digitizing the shoreline and the bathymetric contours onto magnetic tape. The digitized data are processed by the program which creates a grid of depth values by using the straight-line slope formula for depths between the contours.

LINEAR WAVE THEORY

General Description

Linear wave theory, as developed by Airy (in 1845) is a first-order theoretical approximation describing wave behavior. The theory assumes long trains of uniform waves with long unbroken wave crests. Obviously, this condition is not met in areas of locally generated seas, where wave forms may consist of several periods and directions and broken wave crests. However, swell waves, which are outside the area of generation, approximate the above assumption (Komar, 1976). Higher-order theories, usually referred to as finite amplitude theories, increase the number of successive approximations in order to describe more closely the actual wave behavior. These successive approximations serve as correction factors for preceding terms (Coastal Engineering Research Center, 1973, p. 2-2).

Linear wave theory is more commonly used in the study of wave behavior because it is reliable over a number of wave conditions and mathematically easy to apply. Dobson (1967), using linear wave theory in the refraction of incoming waves, developed the original version of the computer program used in this study. Therefore, the celerity of the wave is dependent on the water depth. Refraction or the bending of wave orthogonals (rays or lines parallel to the direction of wave propagation) are a result of the different speeds along the wave crest as it passes over an uneven topography. Simply stated, a wave ray will refract toward shallower water. Because of this interaction between waves and the offshore topography, there is a variation in wave characteristics (height, energy, etc.) in the nearshore zone. This spatial variation in wave characteristics may be a driving mechanism

for nearshore circulation patterns (Noda, 1974; Sonu, 1972). Qualitatively, zones of potential erosion or deposition can be inferred to correspond to converging or diverging wave rays, respectively.

Breaker wave height is a function of the deep water wave height after it has been modified by refraction and shoaling in shallow water. Although Dobson considered frictional attenuation of wave height to be insignificant, Goldsmith (1976) states that friction may cause a significant loss in wave energy and height. Because of the frictional loss of energy over the wide shallow shelf of the Virginian Sea, wave heights were reduced 50 to 75 percent for longer wave periods. This percentage will be less for smaller period waves.

A friction routine similar to the one used by Goldsmith (personal communication) and Coleman and Wright (1971) was added to REFRAC, the wave-refraction program used in this study. However, the resulting wave heights and energy are questionable. Therefore, a quantitative evaluation of wave heights was not attempted.

Assumptions and Limitations

In relation to wave refraction, the main assumptions in linear wave theory are (Coastal Engineering Research Center, 1973, p. 2-65):

(1) Wave energy between wave rays remains constant. This assumption is suspect when wave orthogonals bend sharply as energy may be transferred along the wave crests. Caustics, which are rays that bend sharply enough to cross, no longer present a problem. According to Chao (1972), wave rays continue on the same path after they pass through a caustic as before the caustic, the only difference being a phase shift.

(2) Wave celerity is a function of water depth. This holds true in linear theory but not necessarily in higher-order theories. An increase in wave height, resulting from either shoaling or refraction will cause a slight increase in the wave velocity. This effect is small (Komar, 1976).

(3) The bottom slope is gentle (less than 1:10). Linear theory is strictly valid only for constant depths, but it will successfully predict wave velocities over a gently sloping bottom (Dobson, 1967).

(4) Waves are long-crested, constant period, and of small amplitude. This is not true for 'confused seas' in their area of generation but does approximate swell conditions. In refraction studies, a spectrum of swell conditions needs to be analyzed to simulate the real world (Goldsmith, 1976).

(5) Reflection of wave energy from a gently sloping bottom is negligible. Caldwell (1949) supports this assumption for slopes of four degrees or less.

DATA INPUT

South Carolina Wave Climate

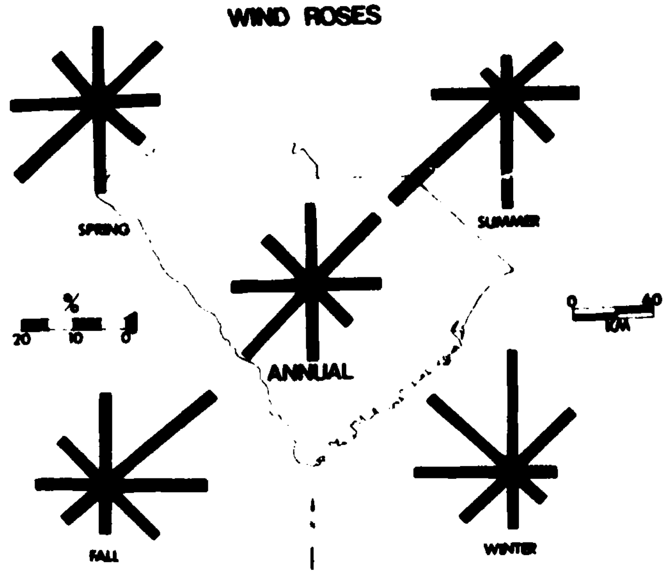
Brown (1977) used SSMO data (U.S. Naval Weather Service Command, 1970) to derive wind and wave-energy-flux diagrams for the South Carolina coast. As expected, seasonal trends in wind and wave conditions were noted (Fig. 2). The average annual wave energy flux on the South Carolina coast is 1.7×10^6 g-m/s^3, with a maximum of 3.1×10^6 g-m/s^3 from the northeast. Wave energy flux is defined as the rate at which wave energy per unit surface area is transmitted in the direction of wave propagation.

The dominant winds (highest velocities) from the north and east during fall and winter are reflected in the direction of the deep water wave-energy flux. Strong storm winds from the northeast are generated by northward passing extratropical storms and are considered by Finley (1976) to be the "most important wave generators". Finley documented 7.3 meters of foredune erosion on Debidue Island in a two-week period following an extratropical cyclone in February 1973. Kana (1977) recorded process measurements during a minor northeast storm in September 1974. An average of 3.8 m^3 of sand per foot of shoreline at Debidue Island was eroded in a 6-hour period. During this short period of erosion, breaker heights were approximately 120 cm (4 ft) with an average wave period of 6 seconds.

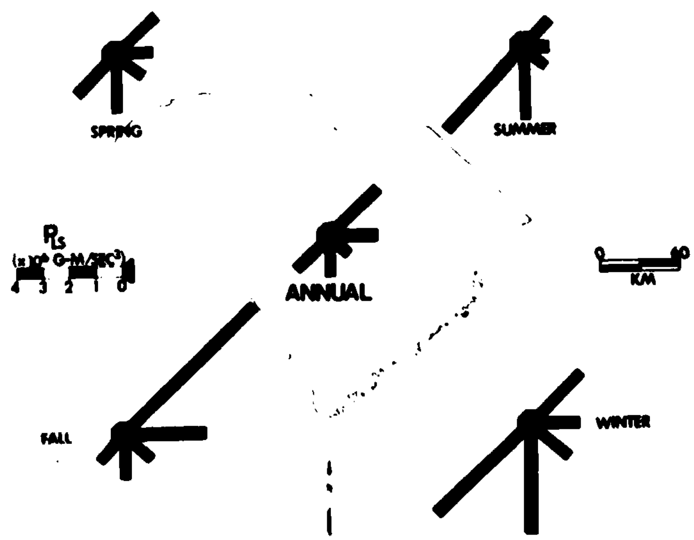
In spring and summer, an increasing frequency of winds are observed from the south and southwest. These winds are generated by an anticyclonic circulation pattern associated with a high pressure zone settling over Bermuda. According to Crutcher and Quayle in Brown (1977), an average of 1.4 hurricanes and tropical storms affect South Carolina's

Figure 2. Seasonal and annual wind and wave energy flux (P_{ls}) roses computed from the 1970 version of SSMO data. Bar length in the wind roses represents the percentage of time the wind blows from any given direction. Bar length in the energy flux roses is a relative measure of the wave energy coming from a given direction (from Brown, 1977).

WIND ROSES



ENERGY FLUXES



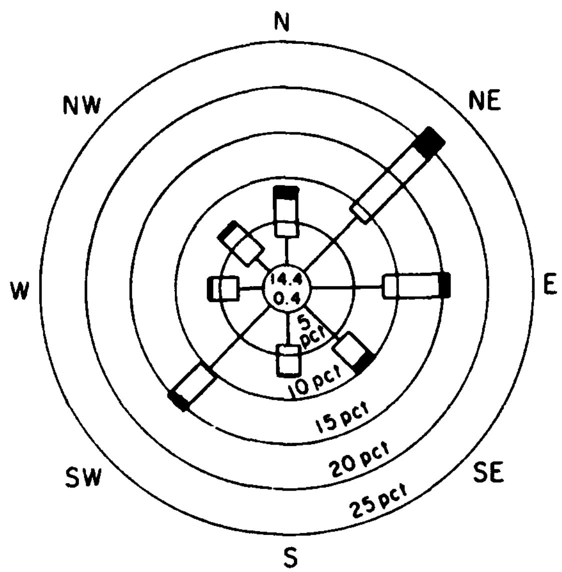
coast annually. The probability of a tropical storm of hurricane force, winds in excess of 74 mph, striking the South Carolina coast, was determined by Nummedal and Humphries (1977) to be about .2, corresponding to one every 5 years. The highest breakers recorded on the coast were approximately 12 ft. They were recorded at Myrtle Beach during a hurricane in 1958 (Nummedal, 1977). Nummedal and Humphries (1977) also noted, from numerous observations at Debidue Island, an 11 cm decrease in wave height for the spring and summer as compared to fall and winter.

The dominant deep water wave-energy flux in the summer, as calculated by Brown (1977), is from the southeast and lower in magnitude than the winter flux values from the northeast and east. Finley (1976) computed the highest sea and swell which could affect the S. C. coast to be from the northeast and east. Figure 3 graphically displays the frequency of occurrence of sea and swell and their approach direction. These SSMO-based wave climate evaluations support the morphologic evidence of a net southward sediment transport.

Based on the above information and 1975 SSMO data, it was decided to use Goldsmith's (1976) "scatter gun" approach with respect to wave input conditions. In this way, a variety of conditions are modeled. Unfortunately, SSMO data have several inherent biases which make it difficult to determine percentage of occurrence for a given wave condition (Goldsmith, 1976; Nummedal and Stephen, 1976).

The initial deep water wave conditions consist of waves propagating from the east (90 degrees), southeast (135 degrees), and from the south (180 degrees) at periods of 10, 8, 6 and 4 seconds with a wave height of 1 foot. An initial wave height of one foot was used at the time of this analysis because frictional attenuation of the wave height in

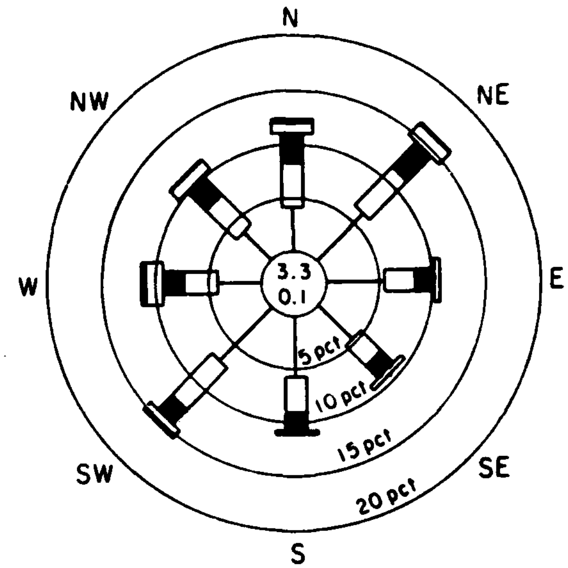
Figure 3. Frequency of occurrence of sea and swell and their approach direction for SSMO observation square off South Carolina (from U.S. Army Corps of Engineers, 1970). (from Finley, 1976).



SWELL DIAGRAM

LEGEND

- Pct No Swell
- Pct Confused
- Low (1 to 6 ft)
- Moderate (6 to 12 ft)
- High (>12 ft)



SEA DIAGRAM

LEGEND

- Pct Calm
- Pct Confused
- Slight (< 3 ft)
- Moderate (3 to 5 ft)
- Rough (5 to 8 ft)
- Very Rough (8 to 12 ft)
- High (> 12 ft)

shallow water was not considered. Therefore, these diagrams are of qualitative value. Calculations of energy and longshore transport can be used for relative comparisons between sections of the coast but should not be used as indicators of absolute magnitudes.

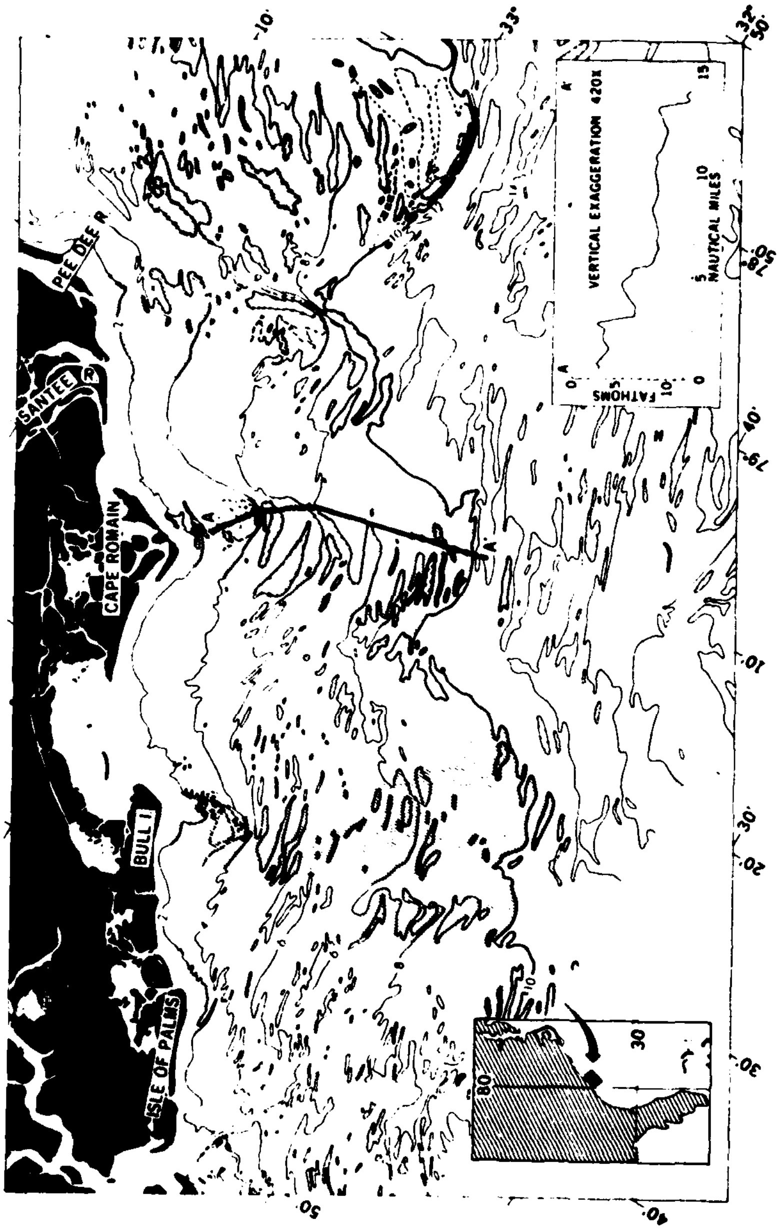
Bathymetry

Shelf morphology. - According to Swift (1976), the Atlantic shelf sands are predominantly generated by erosional shoreface retreat during the Holocene transgression about 11,000 B.P. Two constructional features formed from this sand sheet were shoal retreat massifs which are overlain by linear sand shoals (Swift *et al.*, 1972; Duane *et al.*, 1972). Refer to Figure 4.

Shoal retreat massifs are broad sand ridges of subdued relief, transverse to the shelf, which mark the retreat of nearshore depositional centers. These depositional centers form off capes or cuspate forelands and are the result of littoral drift convergence (Swift, *et al.*, 1972). Because of the closely-spaced forelands south of Cape Romain, the shoal retreat massifs tend to coalesce.

Overlying the shoal retreat massifs are northeast trending linear shoals. These shoals form an angle of approximately 35 degrees with the shoreline, exhibit up to 30 feet of relief and may extend for many miles (Duane *et al.*, 1972). The shoals may be connected to the shoreline or isolated. Duane *et al.* hypothesize that the shoreface connected ridges are formed by storm-generated currents interacting with the shoreface. These ridges become isolated as the shoreline retreats in response to sea level rise. Because of the similarity in orientation of both shoreface-connected and isolated shoals with respect to the shoreline, Duane *et al.* propose that the shoreline orientation pro-

Figure 4. Cuspate forelands and cape shoal-retreat massifs (stippled) of the South Carolina shelf. Note overprinting of ridge and swale topography. Contours are in fathoms. (from Swift, 1976).


PEE DEE R
SANTEE R
CAPE ROMAIN
BULL I
ISLE OF PALMS
VERTICAL EXAGGERATION 420X
FATHOMS
NAUTICAL MILES
A
A'
0
5
10
15
80
30
33°
32°50'
79°
78°50'
40'
30'
20'
10'
50'

bably remained essentially the same during the Holocene marine transgression.

Hydrographic charts. - Depth data is obtained by contouring hydrographic charts and boat sheets printed by NOAA (National Oceanic and Atmospheric Administration). The contoured depths are hand digitized on a Bendix Datagrid Digitizer and stored on magnetic tape. This tape is read by a routine in REFRAC, which constructs a depth grid by interpolating depths between the digitized contours. (For more details, refer to Appendix II)

A first-order chart of the South Carolina shelf (scaled at 1:432,720 to 1:449,659) was used to generate input data onto a larger scaled second-order chart (1:80,000) of the section of coast between Cape Romain and Folly Island. This chart generated data for the larger scaled third-order charts (1:20,000) of Price Inlet. Refer to Fig. 5 and Table 1.

The advantage of this technique lies in the use of more detailed bathymetric data for second and third order charts. This allows increased detail and greater accuracy in the resulting wave-refraction diagrams.

In relation to depth data, two considerations are necessary. First is the accuracy with which the depths were measured. Accuracy criteria for the depths and navigational positioning has been compiled by Sallenger et al. (1975). Refer to Figure 6 and Table 2 for a graphical summary and explanation of this information. Second, the amount of area distortion produced by the Mercator projection from a sphere to a flat map need be insignificant or corrected for. Goldsmith et al. (1974) had a special Mercator projection constructed for the Virginia shelf to minimize distortion. Robinson (1969) and Green-

Figure 5. Graphical representation of the 1st-, 2nd-, and 3rd-order charts and their relation to each other.

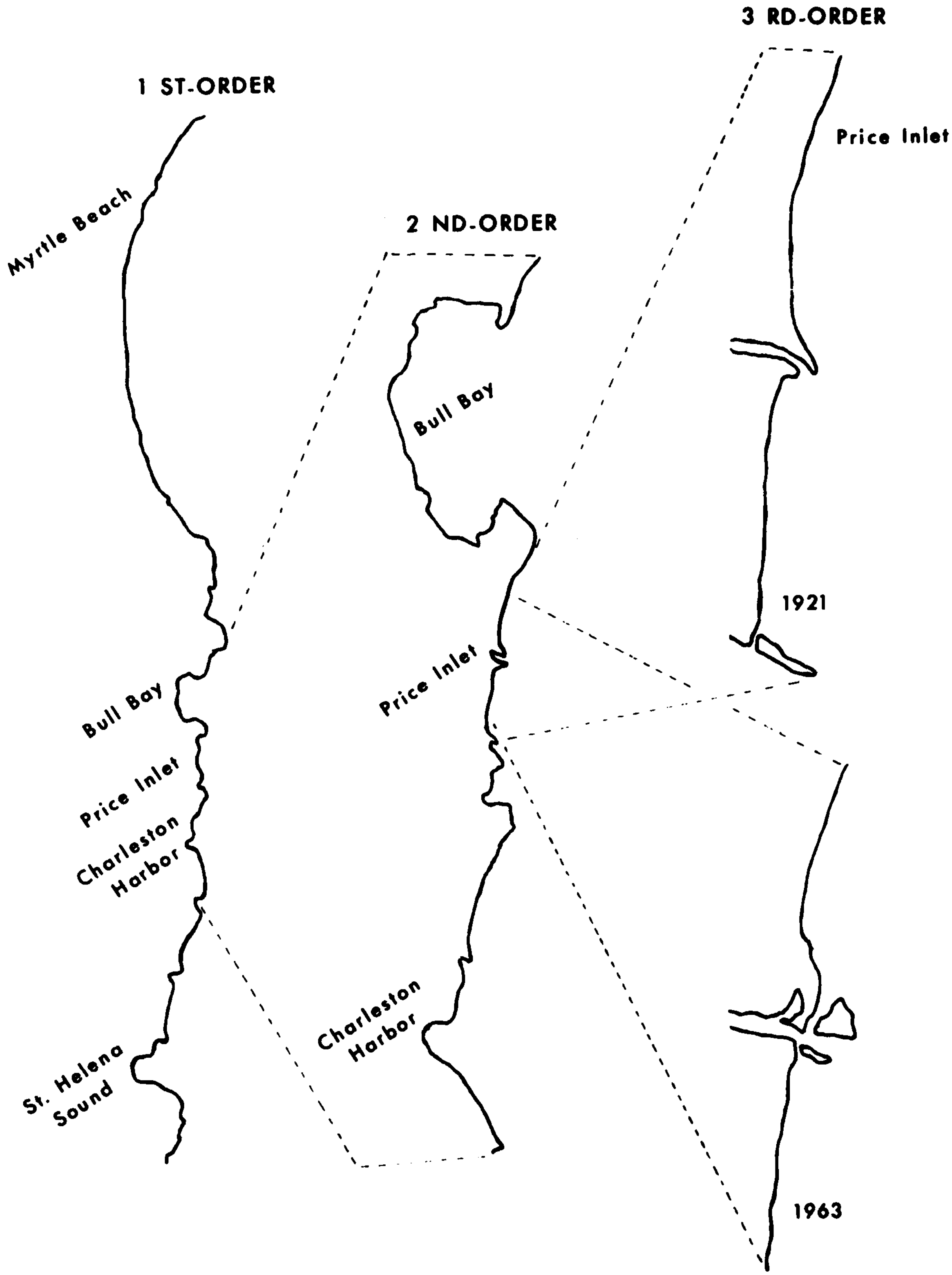
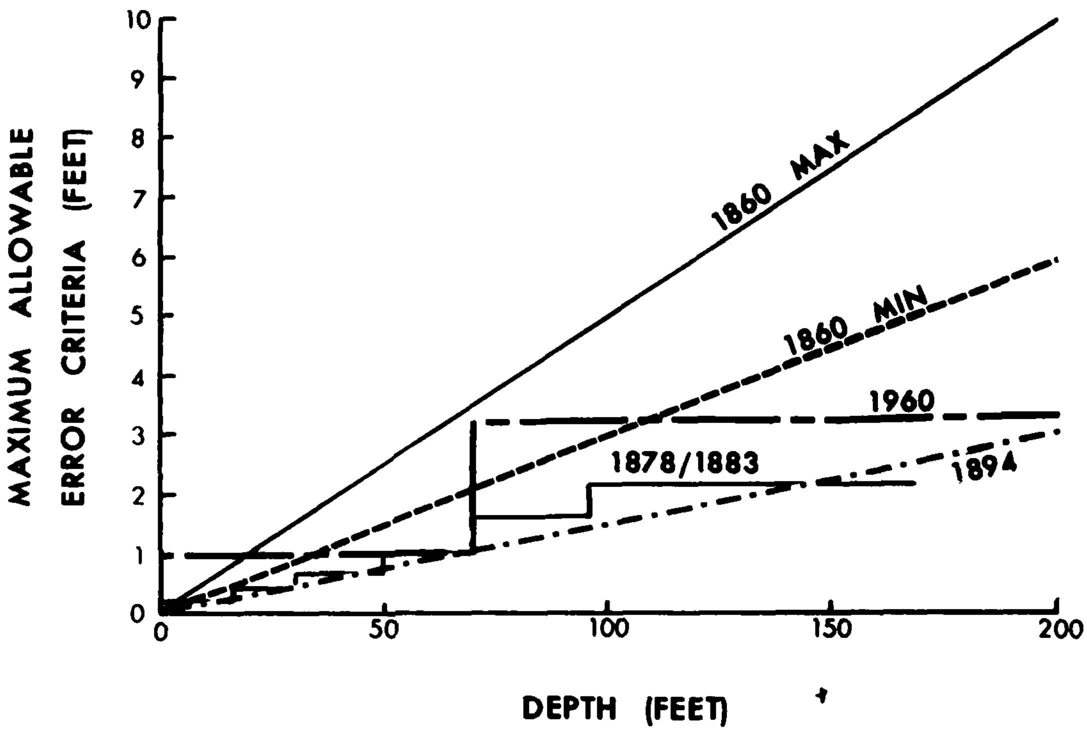

3 RD-ORDER
1 ST-ORDER
Price Inlet
Myrtle Beach
2 ND-ORDER
Bull Bay
1921
Price Inlet
Bull Bay
Price Inlet
Charleston
Harbor
Charleston
Harbor
St. Helena
Sound
1963

Table 1. Hydrographic Chart Information

	Charts	Area	Year	Scale
1ST ORDER	11520	S.C.	1975	1:432,720
	11480	coast	1975	1:449,659
2ND ORDER	1238	Cape Romain	1973	1:80,000
		to Folly Is.	1973	1:80,000
3RD ORDER	H-8779	Price	1963	1:20,000
	H-4179	Inlet	1921	1:20,000
	H-4180		1921	1:20,000

Figure 6. Maximum accuracy criteria used for soundings on hydrographic charts since 1860. Modified from Sallenger (1975). Refer to Table 2 for detailed explanation of this figure.



MAXIMUM ALLOWABLE ERROR CRITERIA (FEET)
10
9
8
7
6
5
4
3
2
1
0
0
50
100
150
200
DEPTH (FEET)
1860 MAX
1860 MIN
1960
1878/1883
1894

Table 2. Historical Review of Sounding Accuracy Criteria

Date	Criteria
1860	allowable error at sounding-line crossings was not to be more than 3 percent of the depth, with a limiting error of 5 percent.
1878 and 1883	depth at sounding line crossings were not to exceed in depths of 15 feet and under, two-tenths of a foot; between depths of 15 and 30 feet, three tenths; 30 and 48 feet, five tenths; between 48 and 72 feet, three-fourths of a foot; between 72 and 96, one foot and a half; and between 96 and 150, two feet. In the sea depths, the limit of error should not exceed 1 percent.
1894	the allowable error at sounding line crossings was 1.5 percent of the depth.
1942	in general, in the lesser depths, the differences at sounding line crossings should average not more than 5 percent of the depth and in greater depths not more than 2 percent of the depth.
1960	maximum errors: (1) 0 to 11 fm (0 to 20 m.): 1.0 ft. (0.3 m); (2) 11 to 55 fm (20 to 100 m.): .5 fm. (1.0 m); (3) 55 fm. (100 m) and deeper: one percent of depth

hood (1964) state that the amount of distortion decreases closer to the equator and that for small areas (as compared to the whole globe) may be negligible. The South Carolina coast lies between 32°N and 34°N and so qualifies as a small area. Therefore, the standard Mercator projections issued by NOAA were used without modification.

DATA OUTPUT - WAVE-REFRACTION DIAGRAMS

Description

A complete description of the types of output, including sample listings of the wave parameters printed by REFRAC, can be found in Appendix II. Refraction diagrams referred to in this section are in Appendix I. (Arrows refer to direction of sediment transport.)

Wave-refraction diagrams are a graphical representation of the bending of wave rays as the waves interact with the continental shelf. This interaction results in an uneven distribution of wave characteristics along the shoreline, as inferred by zones of converging and diverging wave orthogonals. Converging wave orthogonals depict areas of increased wave height and energy commonly correlative with areas of erosion. Conversely, diverging orthogonals depict areas of lower wave height and energy commonly correlative with areas of deposition. To accurately delineate these areas of erosion and deposition for a segment of the S. C. coastline, a set of first-, second-, and third-order wave-refraction diagrams have been generated.

A first-order diagram shows the gross energy distribution over an extended area. Figure 1, for example, shows the over-all wave-refraction pattern on the S. C. continental shelf for waves with a 10-second period from the east. The shelf break ranges from between 47 km and 75 km offshore at the 75 to 100 fathom contour. Figure 2 is a second-order diagram showing the energy distribution between Bull Island and the Isle of Palms. This figure was generated from the first-order diagram shown in Figure 1. The increase in detail is the result of an increase in the density of wave rays refracted and the greater bathymetric detail of the 2nd-order chart. The rays were started in deep water

about 1 km apart. A subset of the rays refracted in Figure 2 generated the third-order diagrams in Figures 6a and 6b. The deep water spacing between these rays is the same as in Figure 2. These third-order diagrams show the detailed wave-energy distribution on Price Inlet's ebb-tidal delta.

The bathymetry of Price Inlet was surveyed in 1921 (PI - 1921) and again in 1963 (PI - 1963). The maximum depth of both surveys is between 25 and 30 feet. Incoming waves with periods of 6 seconds or greater have already felt bottom and begun to refract by the time they reach the maximum depth of the above surveys. Therefore, what is being observed on these charts is the 'fine tuning' of a process that has already begun in water deeper than 30 feet. Since the same second-order hydrographic chart generated input data at the seaward extent of both 3rd-order charts, wave refraction diagrams for PI-1921 and PI-1963 are similar. Changes of the inner shelf bathymetry have been noted by Goldsmith et al. (1975) off the southern Delmarva Peninsula, Virginia. Unfortunately, a smaller scale chart for 1921 was unobtainable.

Only 2nd- and 3rd-order refraction diagrams will be described in detail. Figures 2-5 are 2nd-order diagrams of waves approaching from the east. These waves, typical of winter months, are generated by extratropical storms passing north of South Carolina. A study of these figures reveals the strong effect offshore bathymetry has on an easterly wave approach. Waves with a period of 10 seconds (Fig. 2), after interacting with the continental shelf, have an exceptionally nonuniform distribution of wave energy. A very strong zone of convergence exists at Capers and Dewees Inlets and Capers Island. A dramatic decrease in wave energy is observed south of Dewees Inlet

and north of Price Inlet. The direction of sediment transport was calculated by REFRAC to be predominantly to the south. In analyzing these diagrams, it is important to remember the variability in the amount of sand being transported as a result of the nonuniform distribution of wave energy. For example, in Figure 2, more sand is capable of being transported at Capers and Dewees Islands and their adjoining inlets because of the increased wave energy than further south on the Isle of Palms. Therefore, from Figure 2 alone, deposition may be expected on the Isle of Palms because of the lower wave energy and the resulting decrease in competency of the longshore currents.

Figure 3 is a wave refraction pattern for 8-second waves from the east. The wave energy, as compared to Figure 2, is more evenly distributed. A strong zone of convergence exists in the central section of the Isle of Palms and the northern tip of Bull Island. Price Inlet and the remainder of Bull Island seem to be in a zone of reduced wave energy for both 10- and 8-second waves. The predominant direction of sediment transport for an 8-second wave is to the south.

Refraction diagrams for waves with periods of 6- and 4-seconds (Figs. 4 and 5, respectively) have a progressively more uniform wave energy distribution than the energy distribution for 8- and 10-second waves. This results from longer period waves beginning to refract in deeper water. Furthermore, as a result of the different depths in which waves of varying periods begin to refract, the orthogonals of waves with longer periods tend to be more perpendicular to the coast (compare Figs. 2-5). Figure 4 (period (T)=6 seconds) shows a zone of convergence on the shoals north of Price Inlet. Sediment transport is predominantly to the south except on these northern shoals

where it is to the north. In Figure 5 (T=4 sec), the zone of convergence has shifted to the southern shoals of Price Inlet and the northern end of Capers Island. The sediment transport is predominantly to the south, including the northern shoals of Price Inlet. The difference in transport direction on the northern shoals of Price Inlet is explained by the more perpendicular orientation of the wave rays with the shore, for waves with a longer period. This implies that shorter period waves may actually enhance sediment bypassing at Price Inlet.

Third-order refraction diagrams show the energy distribution and resulting sediment transport at Price Inlet in greater detail. The direction of sediment transport at the northern shoals of Price Inlet is to the south in Figures 9a and 9b (T=4 sec); whereas, for 10-, 8-, and 6-second waves (Figs. 6-8) transport is to the north. Comparing the direction of sediment transport in Figs 6a-9a and 6b-9b reinforces the above observation that sediment bypassing at the distal margin of the ebb-tidal delta of Price Inlet may be enhanced by waves with a shorter period. Further analysis of these diagrams reveals the existence of sediment transport reversals south of the inlet (Figs.7a and 9b). Sediment transport reversals are caused by the refraction of waves around an ebb-tidal delta. Finley (1976) documented a similar transport reversal at North Inlet, South Carolina. Another observation, seen in Fig. 8a (T=6 sec), is the strong convergence of wave rays at the seaward extent of the northern marginal flood channel.

During the summer months, storms generate waves from the southeast and south. Second-order diagrams of waves from the southeast are shown in Figs. 10-13. The influence of the offshore bathymetry on these waves is evidenced by the alternate zones of converging and

diverging wave rays. Contrary to waves from the east, the zones of wave energy concentration do not shift with a change in period. For waves from the southeast with periods of 10-, 8-, and 6-seconds (Figs. 10-12), strong zones of convergence occur at the southern end of the Isle of Palms (Breach Inlet) and the northern section of Capers and Bull Islands. A weaker concentration of wave energy is seen at Dewees Inlet. The only difference between periods is the degree of concentration; smaller period waves are usually not as focused. Zones of reduced energy, such as Price Inlet, exist between the above zones of concentration. Waves with a 4-second period show a comparatively even wave-energy distribution.

The direction of sediment transport was determined to be the same for all 4 periods. Transport is predominantly to the south with an indication of transport to the north at the northern shoals of Price Inlet and Capers Inlet. As seen from the third-order refraction diagrams (Figs. 14-17), the predominant sediment transport is also to the south, but with one important difference. A sediment transport reversal to the north exists at the southern shoals of Price Inlet in all the diagrams except Figure 17b, which is for a wave with a period of 4-seconds.

Waves from the south are not affected as much by the offshore bathymetry as waves from the east and southeast. As a result, wave energy is more evenly distributed (Figs. 18-21). Fig. 18 (T=10 sec) shows zones of minor concentration at the southern and northern ends of the Isle of Palms. Bull Island experiences a slight increase in wave energy at the southern and central sections of the island. A more even energy distribution is seen in Fig. 19 (T=8 sec), except

for a strong concentration of wave rays on the mid-section of the Isle of Palms. This zone is surrounded on either side by a reduction in wave energy. Figs. 20 (T=6 sec) and 21 (T=4 sec) have a fairly uniform energy distribution. The only difference is seen in the direction of sediment transport. Figs. 18-21 show a dominant transport to the north. However, for waves with a 10-, 8-, and 6-second period, the sediment transport on the southern shoals of Price Inlet is to the south (Figs. 18-20). Transport is to the north for a wave with a 4-second period (Fig. 21). By comparing the above 4 figures with the more detailed third-order diagrams, Figs. 22-25, it is apparent that the lack of detail in Fig. 21 accounts for the discrepancy in the transport directions. Fig. 25a and b shows a sediment transport direction to the south for 4-second waves on the southern shoals of Price Inlet.

Discussion

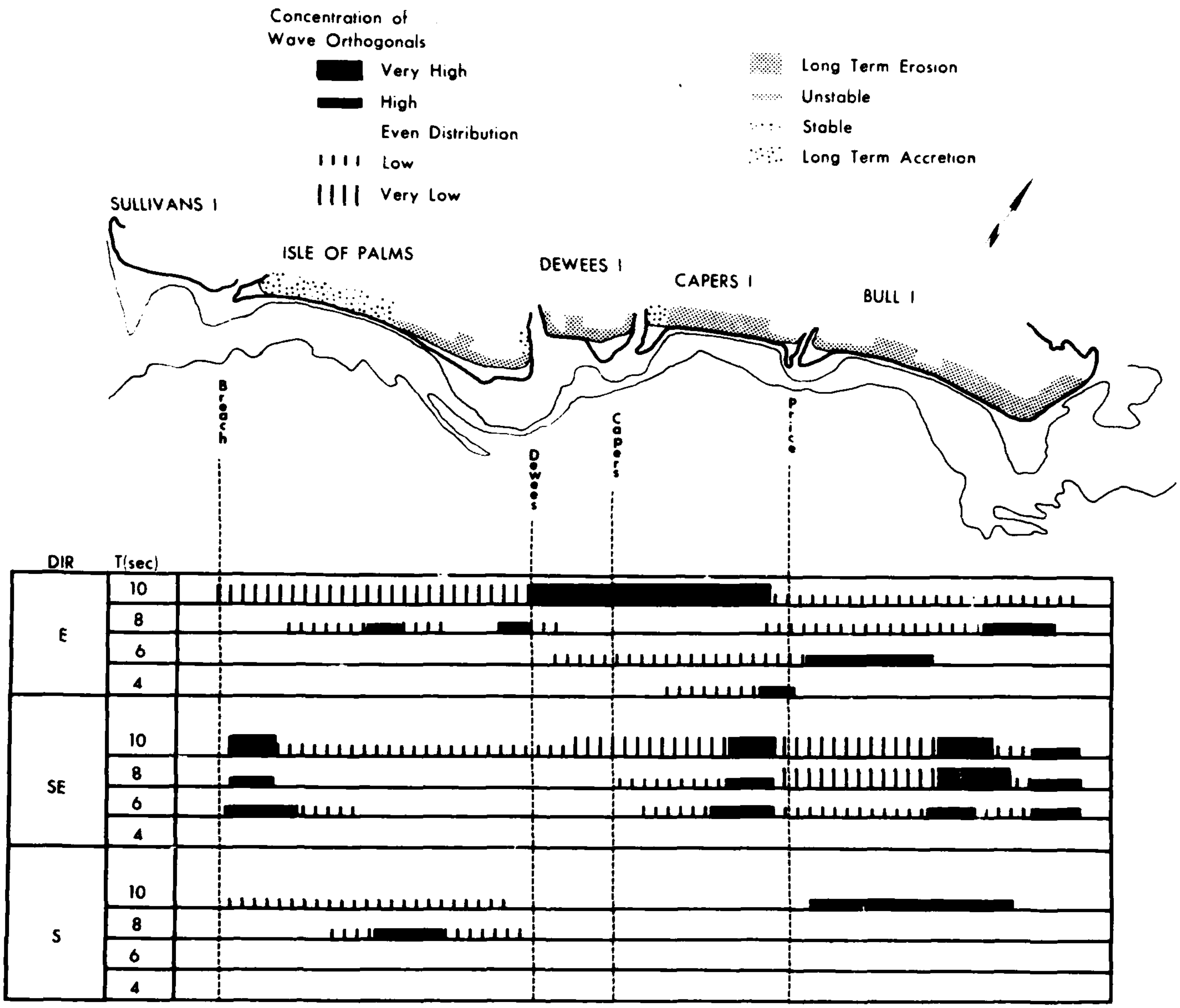
Wave-refraction analysis provides an efficient method for interpreting coastal processes. When used in conjunction with field data, refraction diagrams aid in the understanding of coastal geomorphology. Stephen *et al*. (1975) measured the rates of shoreline change from vertical aerial photographs between the years 1939 and 1973 for Charleston County, South Carolina. The resulting classification scheme has four categories: areas of long-term erosion, long-term accretion, unstable areas and stable areas. Refer to Fig. 7 for an explanation and the geographical location of these categories. Included in this figure are the locations of the zones of wave energy concentration and reduction described in the previous section. A careful analysis of Fig. 7 reveals a relation between the zones of high and low wave energy, as depicted by wave-refraction diagrams, and the coastal geo-

Figure 7. Classification scheme of the shoreline changes for the S. C. coast, based on aerial photographs from 1939 to 1973. Modified from Stephen et al. (1975).

long-term erosion: areas which have undergone relatively continuous erosion over the study interval.
long-term accretion: areas which have undergone relatively continuous deposition over the study interval.
unstable: areas with fluctuations greater than 50 ft over the study interval.
stable: areas with fluctuations of less than 50 ft over the study period.

Superimposed on these shoreline changes are the various degrees of wave ray concentrations observed from the wave refraction diagrams.

exceptionally high concentration
high concentration
uniform distribution of wave rays
low concentration or diverging rays
exceptionally low concentration.


Concentration of Wave Orthogonals
Very High
High
Even Distribution
Low
Very Low
Long Term Erosion
Unstable
Stable
Long Term Accretion
SULLIVANS I
ISLE OF PALMS
DEWEES I
CAPERS I
BULL I
Breach
Dewees
Capers
Price
DIR
T(sec)
E
SE
S
10
8
6
4

morphology.

There is a dynamic interaction between the tidal currents and longshore currents generated by waves which affects the orientation and morphology of ebb-tidal deltas (Oertel, 1975; Oertel and Howard, 1972; Hubbard, 1977). Tide-dominated inlets have well-developed shoals forming a high oblique angle with the shoreline. Waves have a tendency to straighten a coastline by focusing energy on headlands. As a result, wave dominated ebb-tidal deltas have a relatively parallel orientation with the shoreline. Coleman (1976) cites similar behavior in river deltas, only the interaction is between sediments supplied by the river and the wave regime.

Analysis of Fig. 7 shows the orientation of Price Inlet's ebb-tidal delta to be more normal to the shoreline than the orientation of the Capers-Dewees shoal complex further to the south. One explanation for this is obtained by comparing the refraction patterns on these inlets. Price Inlet exists essentially in a shadow zone of reduced wave energy for waves from the east, which is the direction of dominant energy flux. Therefore, tidal currents play a more active role in the development of the ebb-tidal delta, resulting in an almost perpendicular orientation to the shoreline. The Capers-Dewees complex, however, lies in a zone of exceptionally high wave energy concentration for a 10-second wave from the east. As a result, waves tend to push the sand up against the shore causing a more oblique or parallel orientation with the shoreline.

Besides the oblique orientation of Dewees Inlet, a large downdrift offset is exhibited. The ebb-tidal delta will act as a barrier against wave attack, but the downdrift offset is probably more

related to a sudden reduction in southward directed longshore drift at the Isle of Palms. This reduction in longshore drift, caused by the nonuniform energy distribution, allows the deposition of sediment on the northern end of the Isle of Palms. The area is unstable because of its proximity to Dewees Inlet.

Figure 7 shows long-term erosion further north at Bull Island. North Bull Island has no protecting shoals and is therefore open to wave attack, especially from an 8- or 6-second wave from the east. Figs. 10-13 (in Appendix I) show a concentration of wave energy on Bull Island for all waves from the southeast. This concentration of wave rays results from the interaction of waves and the section of the shoal retreat massif off the northern end of Bull Island (30 foot contour and shallower). Also, there is no apparent sediment source to allay the erosional trend on Bull Island.

Capers Island is also undergoing long-term erosion. As seen from Fig. 7, strong concentrations of wave energy are noted for waves from the east with a wave period of 10-seconds and waves from the southeast with a period of 10-, 8-, or 6-seconds.

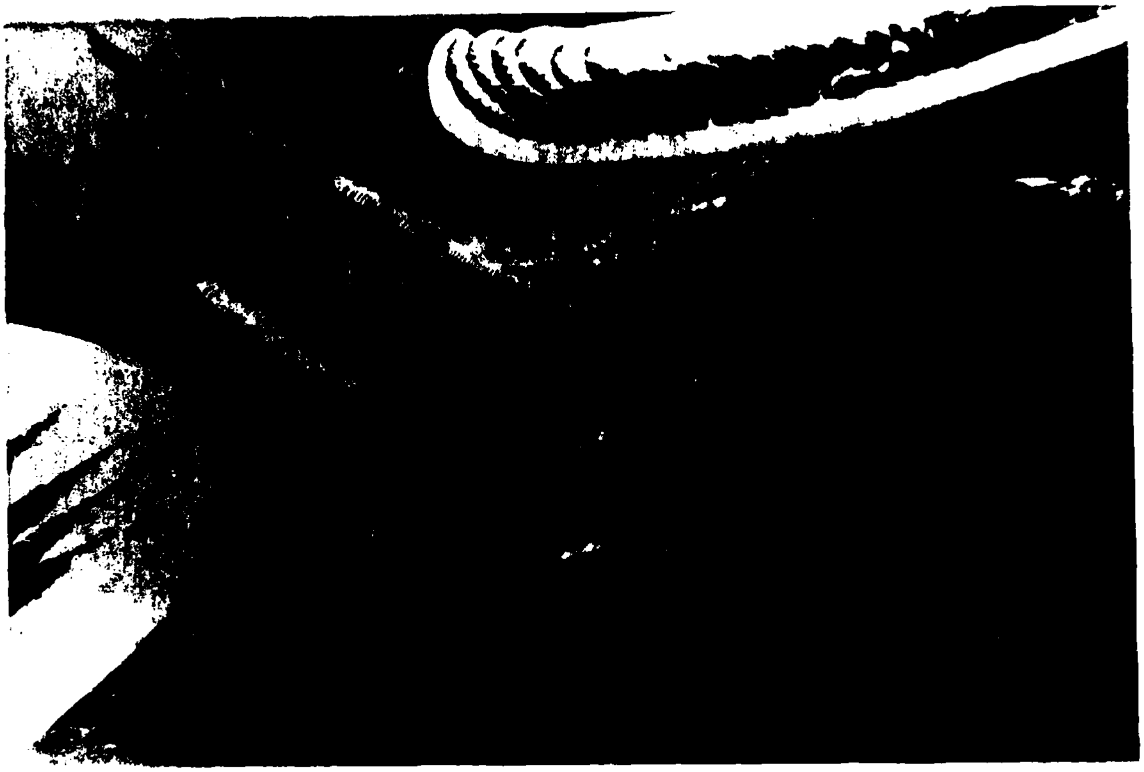
A maximum accretion of 400 feet since 1941 has occurred on the southern end (spit) of the Isle of Palms. This area is one of the few areas on the S. C. coast categorized as long-term accretion. An analysis of Fig. 7 reveals this section of the Isle of Palms to be in a zone of reduced wave energy for most wave conditions. Therefore, deposition and spit growth would be enhanced.

A comparison of Figs. 1-5, 10-13, 18-21 (in Appendix I) and Fig. 7 suggests that longer period waves have more effect on the shape of the coast than shorter period waves. Because of the more

dramatic concentration or divergence of wave rays for longer period waves, sections of the coast will accrete or erode at different relative rates, therefore influencing the gross morphology of the coast to a larger degree than shorter period waves. Shorter period waves will have relatively even rates of erosion or deposition because of their more uniform wave energy distribution. The accretion on the Isle of Palms, the downdrift offset at Dewees Inlet, and the orientation of Dewees Inlet as compared to Price Inlet support this observation. The possibility that longer period waves have more effect on coastal geomorphology implies that the deeper offshore bathymetry (greater than approximately 48') affects the coast more than the nearshore bathymetry. To determine the validity of this observation, more precise data on the frequency of various wave conditions is necessary.

To gain an understanding of wave refraction and its possible effects on the morphology of an ebb-tidal delta, refraction diagrams with greater detail were generated for Price Inlet. Price Inlet is an example of a model developed by Hayes (1975) on ebb-tidal deltas (Fig. 8). Basically, waves will bend toward the inlet. The angle the wave makes with the shoreline is of critical importance in determining the direction of sediment transport. Waves from the east and southeast have a predominant sediment transport to the south. A careful examination of Figs. 6-9, 14-17 (in Appendix I) shows sediment transport reversals south of the ebb-tidal delta. Transport reversals result from the sharp bending of wave rays around the delta and provide a means for both reintroducing sand into the inlet, through the marginal flood channels, and building the beach and

Figure 8. General ebb-tidal delta model (from Hayes, 1975).



shoals south of the inlet. This mechanism was proposed by Hayes et al. (1970) as being responsible for downdrift offsets.

The angle at which waves strike the ebb-tidal delta may enhance or inhibit sediment bypassing around the distal shoals of the delta. Sand may be transported landward onto the swash platform or along the shoal margins depending on the tide level. At low tide, the shoals are subaerial. As a result, sand transport will occur along the shoal margins. For waves from the east, the net longshore transport is to the south. However, an analysis of Fig. 6-9 (in Appendix I) reveals that on the northern shoals of the delta, sediment transport is to the north for waves with a period of 10-, 8-, and 6-seconds. Therefore, sand transport to the south around the distal end of the delta is inhibited. For a 4-second wave, sediment transport on the northern shoals is to the south and, therefore, may actually enhance sediment bypassing. This is explained by the more oblique approach of a 4-second wave to the shoreline than the longer period waves.

Many of the ebb-tidal deltas on the S. C. coast exhibit channels which run parallel to the shore. During early flood when the swash bars are exposed, these marginal flood channels provide an avenue for water flow and sediment transport into the inlet. In the vicinity of the marginal flood channels, Figures 6-9, 14-17, 22-25 (in Appendix I) show converging sediment transport directions. This convergence may create a hydraulic head at the seaward extent of the marginal flood channel, thereby enhancing water flow and sediment transport through the channels. The larger size of the northern marginal flood channel probably reflects the effects of the direction of dominant wave energy flux from the northeast and east. The wide funnel

shape of this channel may result from the strong convergence in wave rays noted in Fig. 8 (in Appendix I). This convergence of rays would cause both an increase in wave setup and energy resulting in increased sediment transport and erosion at the seaward extent of the flood channel.

In nature, a spectrum of wave conditions strike the shore at any one time. Each component of this spectrum (different period and direction) has its own distribution of wave height and energy. This nonuniform distribution of wave characteristics, caused by wave refraction, may partially explain the intermittent character of the flood-directed stresses noted by Huntley and Nummedal (pers. comm.) in the marginal flood channels. These authors made a series of along-channel and cross-channel velocity measurements in both channels. An analysis of the variability of these two directional velocities provided a measure of the radiation stress available to drive longshore currents in the channels. These stresses were intermittent and related to obliquely incident waves.

CONCLUSIONS

The offshore bathymetry creates zones of converging and diverging wave rays by interacting with waves of different periods and directions. The importance of this interaction of coastal geomorphology is seen in the following observations from wave refraction diagrams of the S. C. coast from Bull Island to the Isle of Palms:

1. Zones of high and low wave energy, as depicted by converging and diverging wave rays, tend to have corresponding zones of erosion and deposition. Both Bull Island and Capers Island which are undergoing long-term erosion, are located in areas of wave convergence. Bull Island lacks an apparent sediment source which may partially account for the erosion. Further south, the southern tip of the Isle of Palms has undergone extensive deposition. This section of the Isle of Palms corresponds to a zone of reduced wave energy.

2. The large downdrift offset of Dewees Inlet appears to be related to a sudden reduction in the southward-directed longshore drift at the Isle of Palms as compared to Dewees Island and other barriers further north.

3. The orientation of Dewees Inlet and Price Inlet is related to the balance between wave energy and tidal energy. Price Inlet, being in a zone of wave energy reduction, is relatively dominated by the tidal current resulting in a normal orientation to the shoreline. Dewees Inlet exhibits an oblique orientation with the shoreline. This orientation is strongly related to the exceptionally high concentration of wave energy received from a 10-second wave from the east.

4. This study suggests that longer period waves and, therefore, the deeper offshore bathymetry may have a stronger effect on the

coastal geomorphology than shorter period waves and the nearshore bathymetry. Evidence for this is seen by the accretion on the Isle of Palms, the downdrift offset at Dewees Inlet, and the shore-parallel orientation of Dewees Inlet.

5. Sediment transport reversals are seen at Price Inlet for waves from the east and southeast. The calculated direction of transport implies that these reversals provide a means for reintroducing sand into the inlet and depositing sand on the beach, and shoals south of the inlet.

6. Sediment bypassing around the distal portion of the ebb-tidal delta at Price Inlet may be enhanced by shorter period waves from the east.

7. In relation to marginal flood channels at Price Inlet, the following observations were made:

a) Hydraulic heads resulting from the convergence of two different directions of transport may enhance water flow and sediment transport through the flood channels.

b) A wave with a period of 6-seconds from the east may account for the funnel shape of the seaward extent of the northern marginal flood channel because of the strong zone of convergence in the vicinity.

c) The pulsating flood currents recorded by Huntley and Nummedal (pers. comm.) may partially be explained by the variations in wave height produced at a point due to the simultaneous refraction of several different wave conditions.

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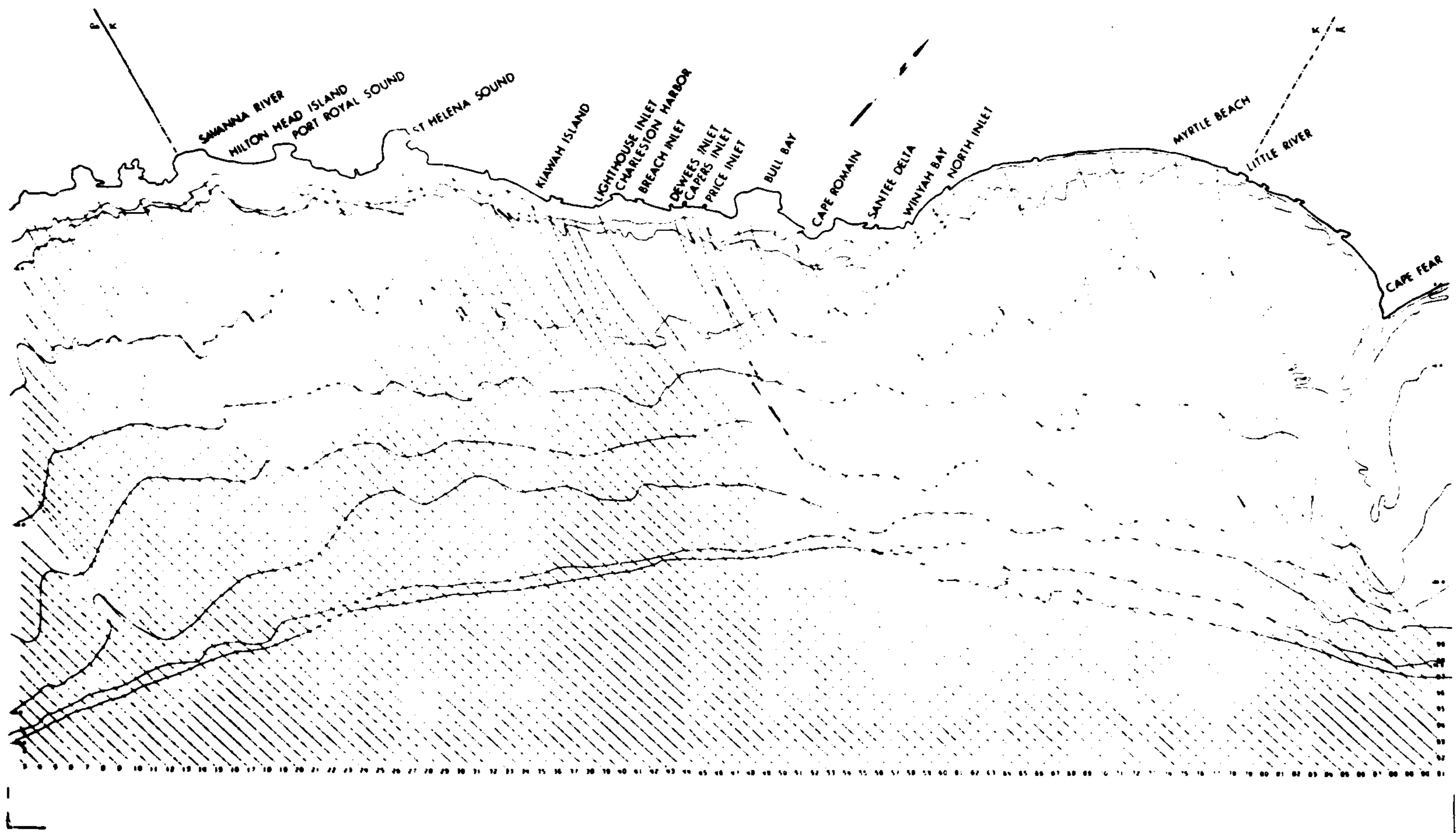
APPENDIX I

Refraction Diagrams



SOUTH CAROLINA COAST

FIG 1

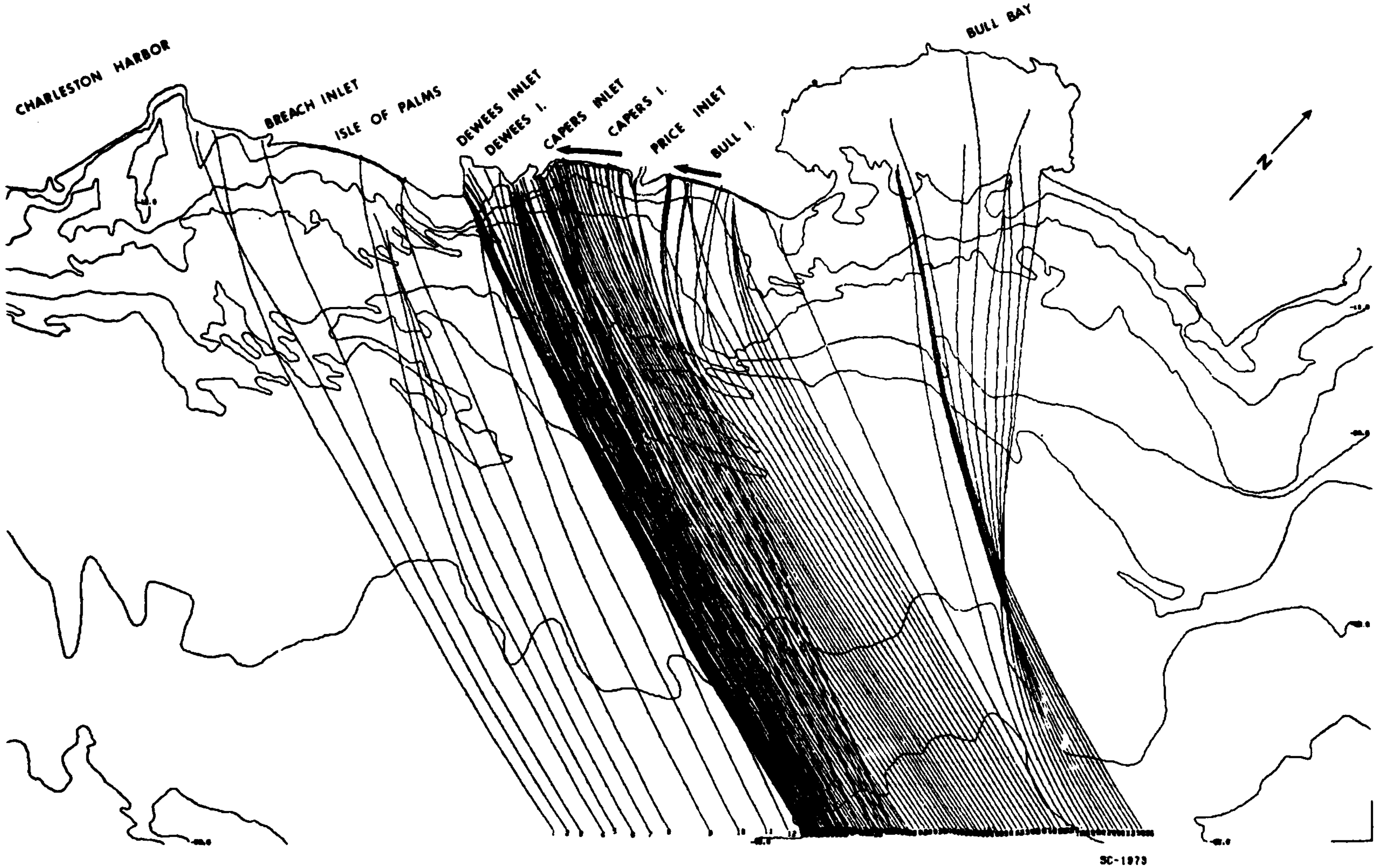

CHARLESTON HARBOR
BREACH INLET
ISLE OF PALMS
DEWEES INLET
DEWEES I.
CAPERS INLET
CAPERS I.
PRICE INLET
BULL I.
BULL BAY
N
SC-1973

FIG. 2

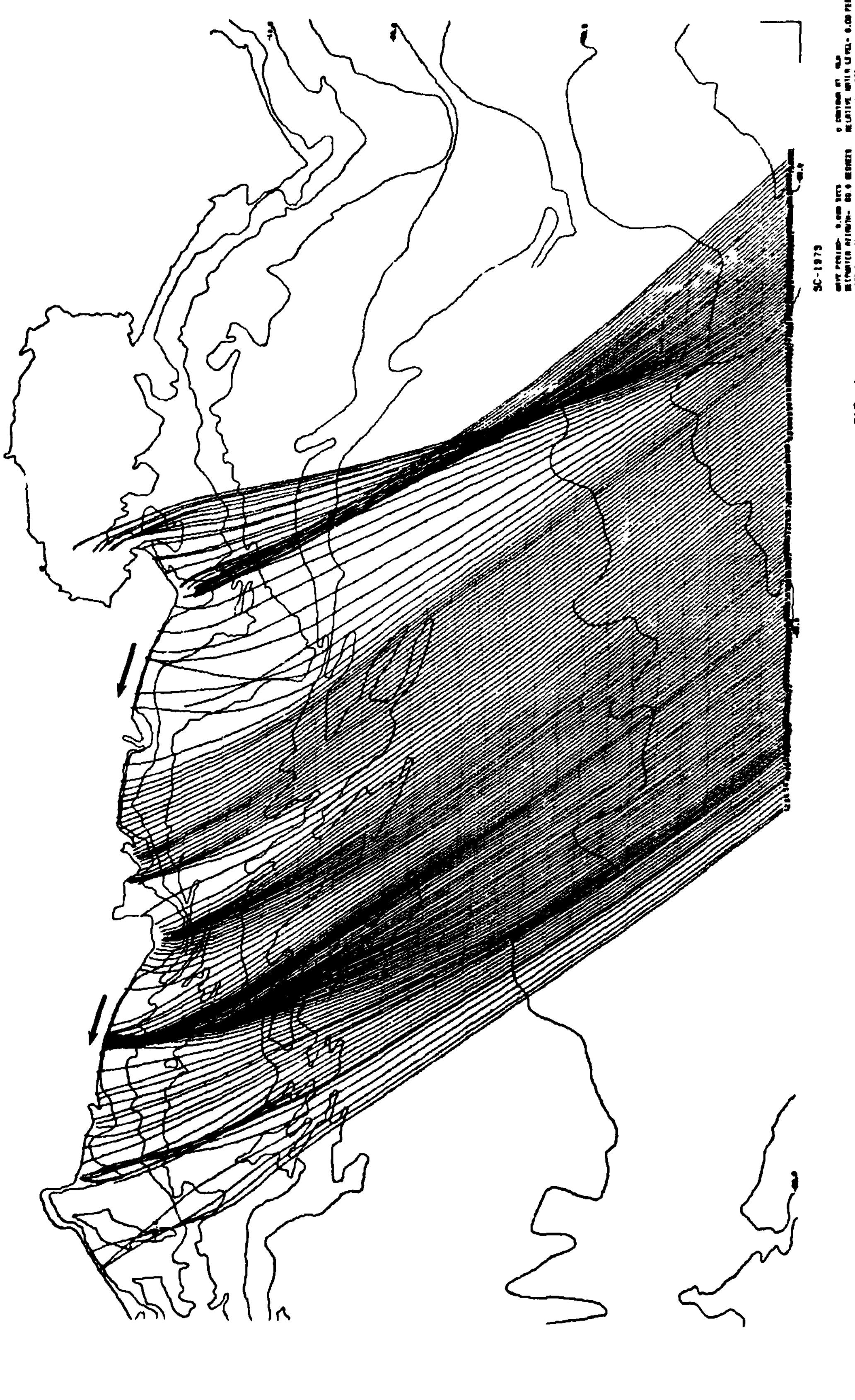


FIG. 3

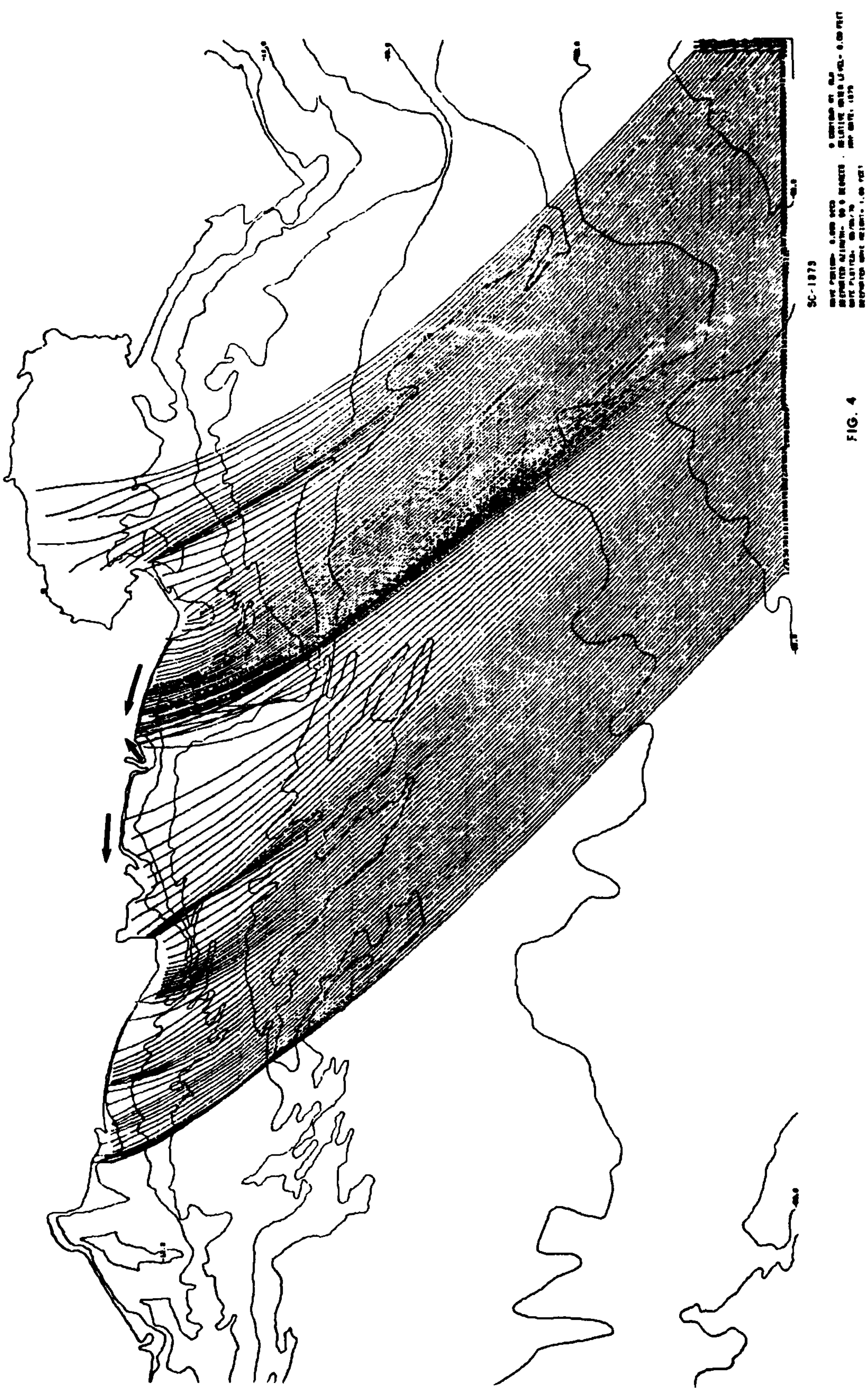


FIG. 4

SC-1973

FIG. 5

PI-1963 T10R90

FIG. 6a WAVE PERIOD= 10.000 SECS
DEEPWATER AZIMUTH= 90.0 DEGREES
DATE PLOTTED: 05/16/78
DEEPWATER WAVE HEIGHT= 1.00 FEET

0 CONTOUR AT MLW
RELATIVE WATER LEVEL= 0.00 FEET
MAP DATE: 1963

PI-1921 T10A90

WAVE PERIOD= 10.000 SECS
DEEPWATER AZIMUTH= 90.0 DEGREES
DEEPWATER WAVE HEIGHT= 1.00 FEET
0 CONTOUR AT: MLW
RELATIVE WATER LEVEL= 0.00 FEET
MAP DATE: 1921

FIG. 6b

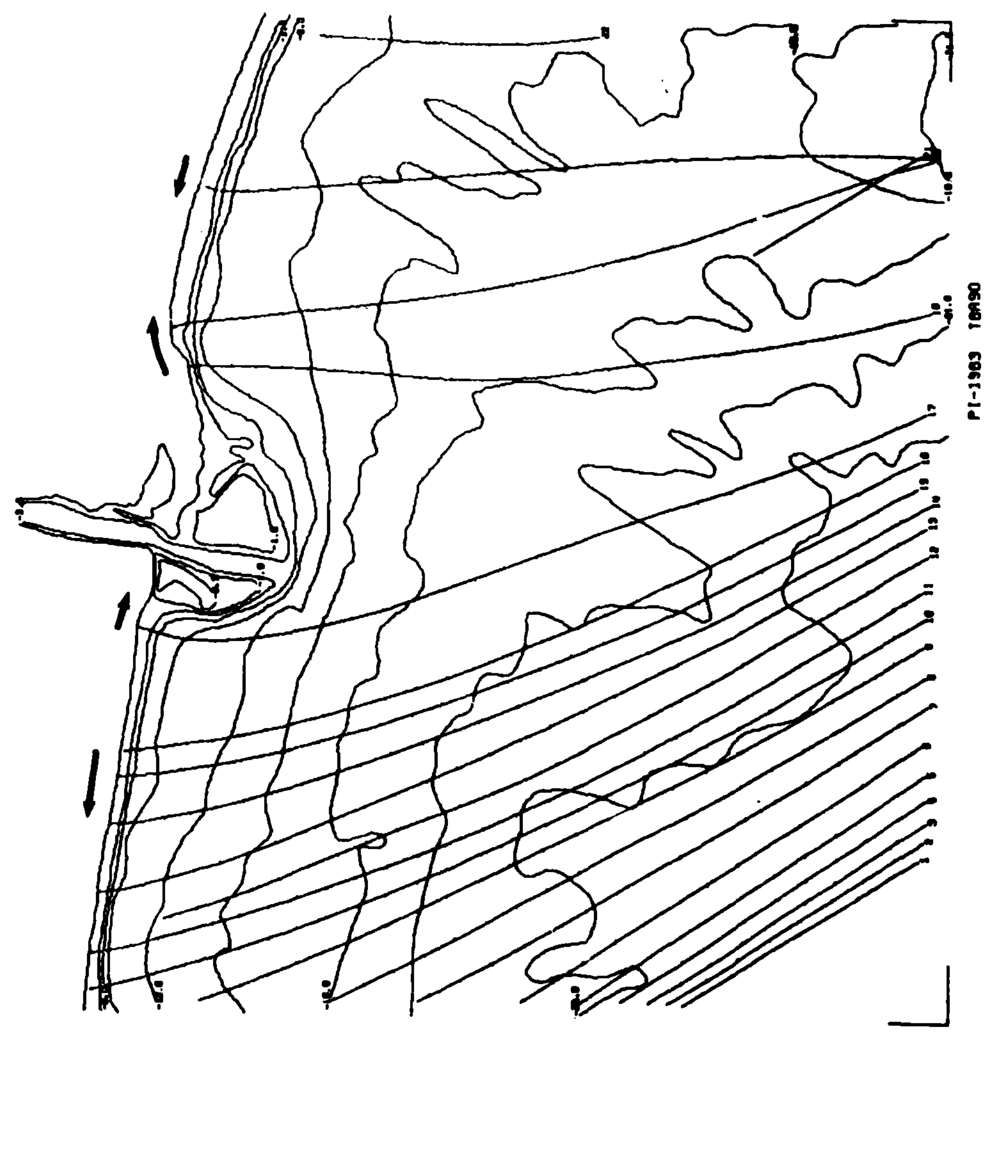


FIG. 7a

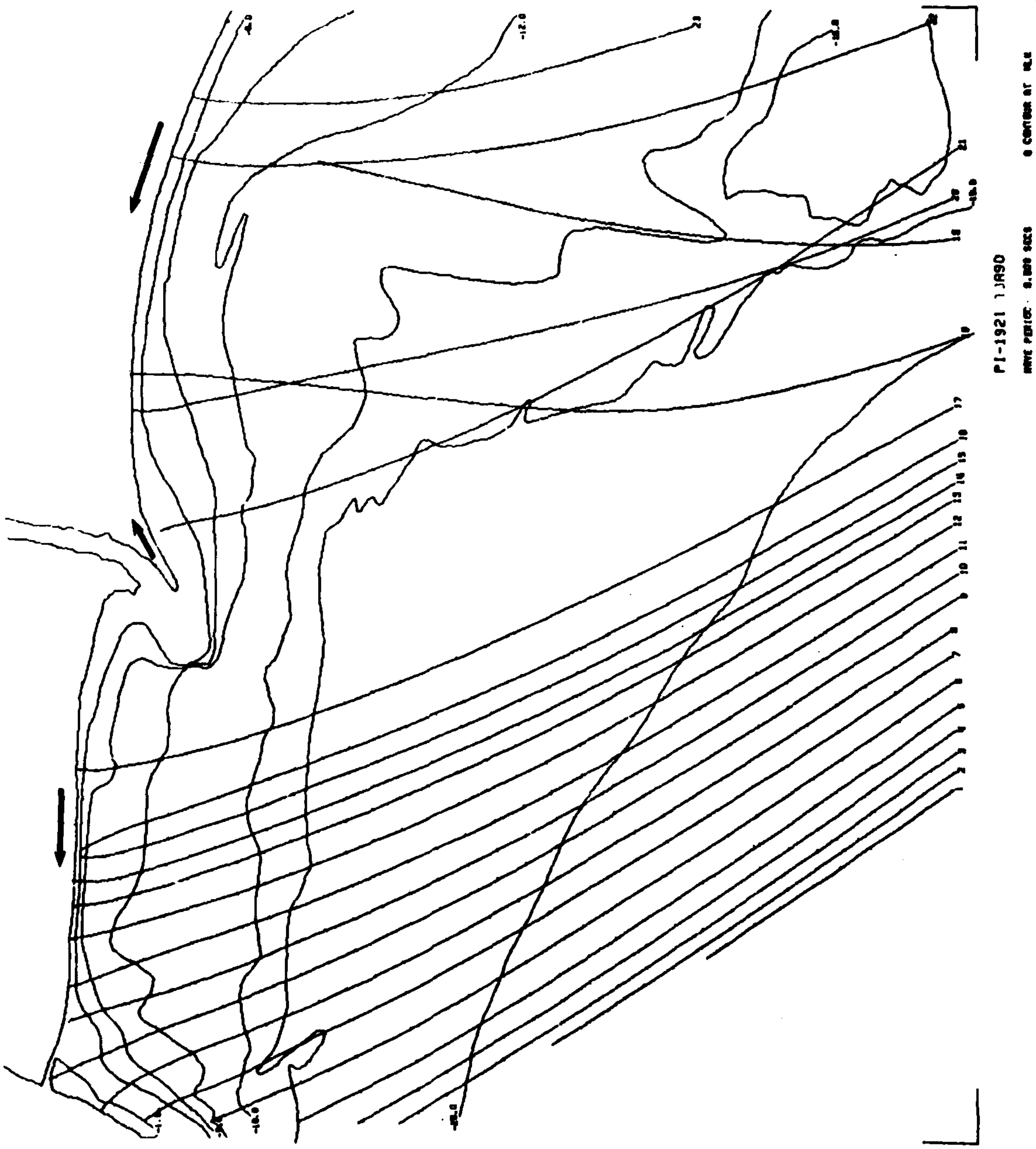


FIG. 7b

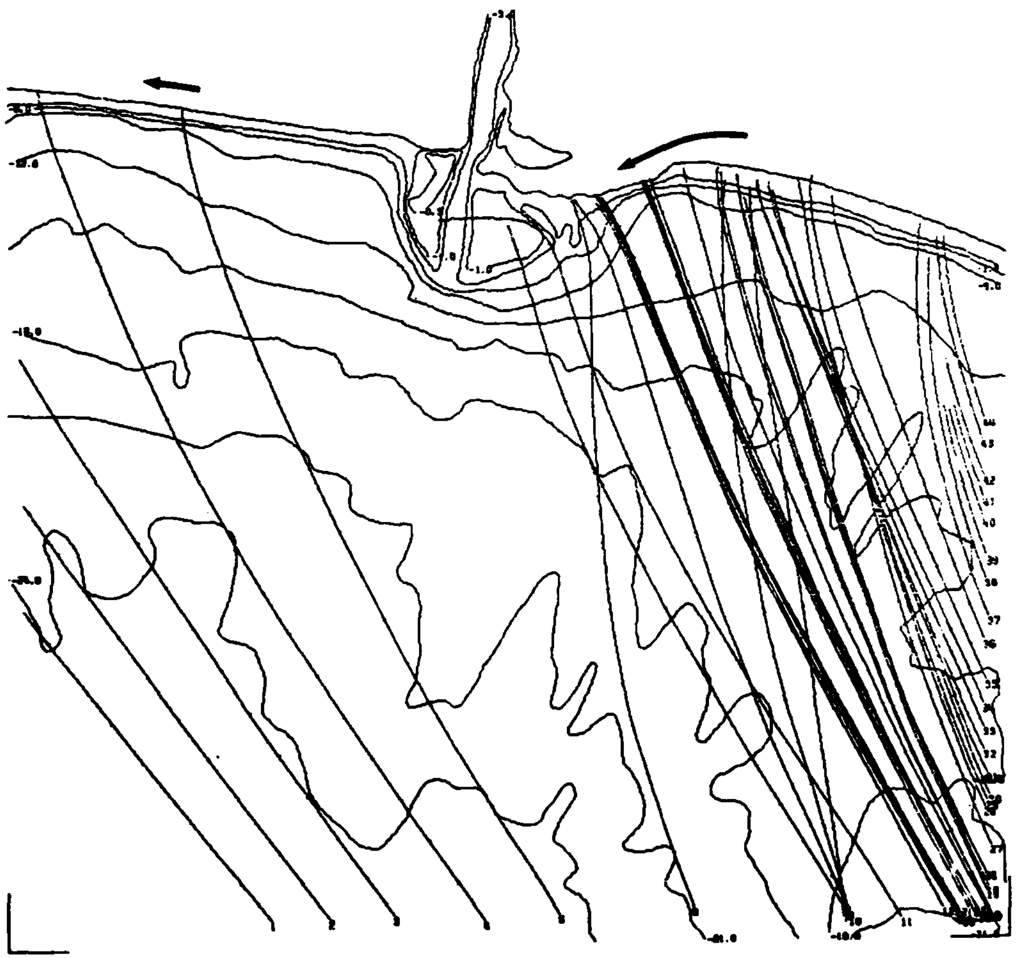


FIG. 8a

FIG. 8b

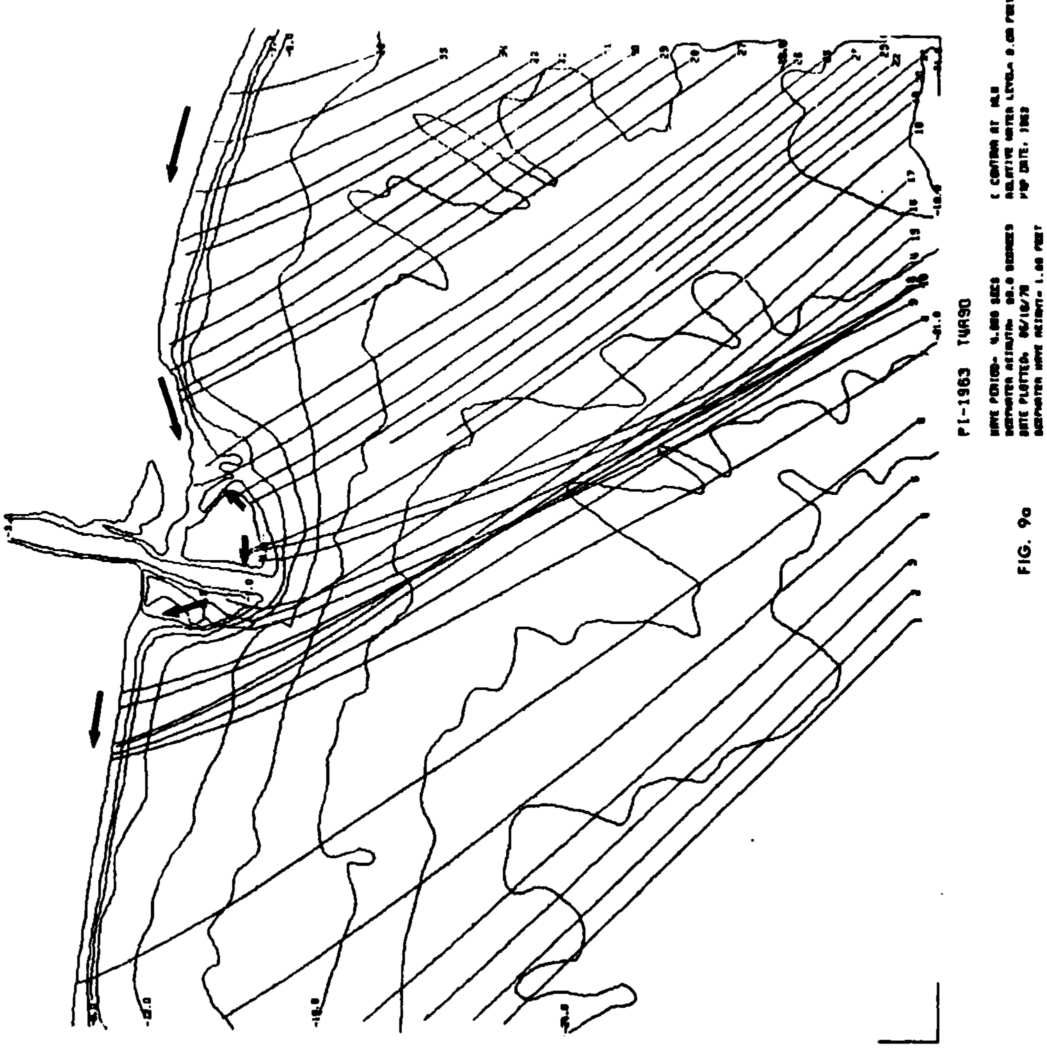
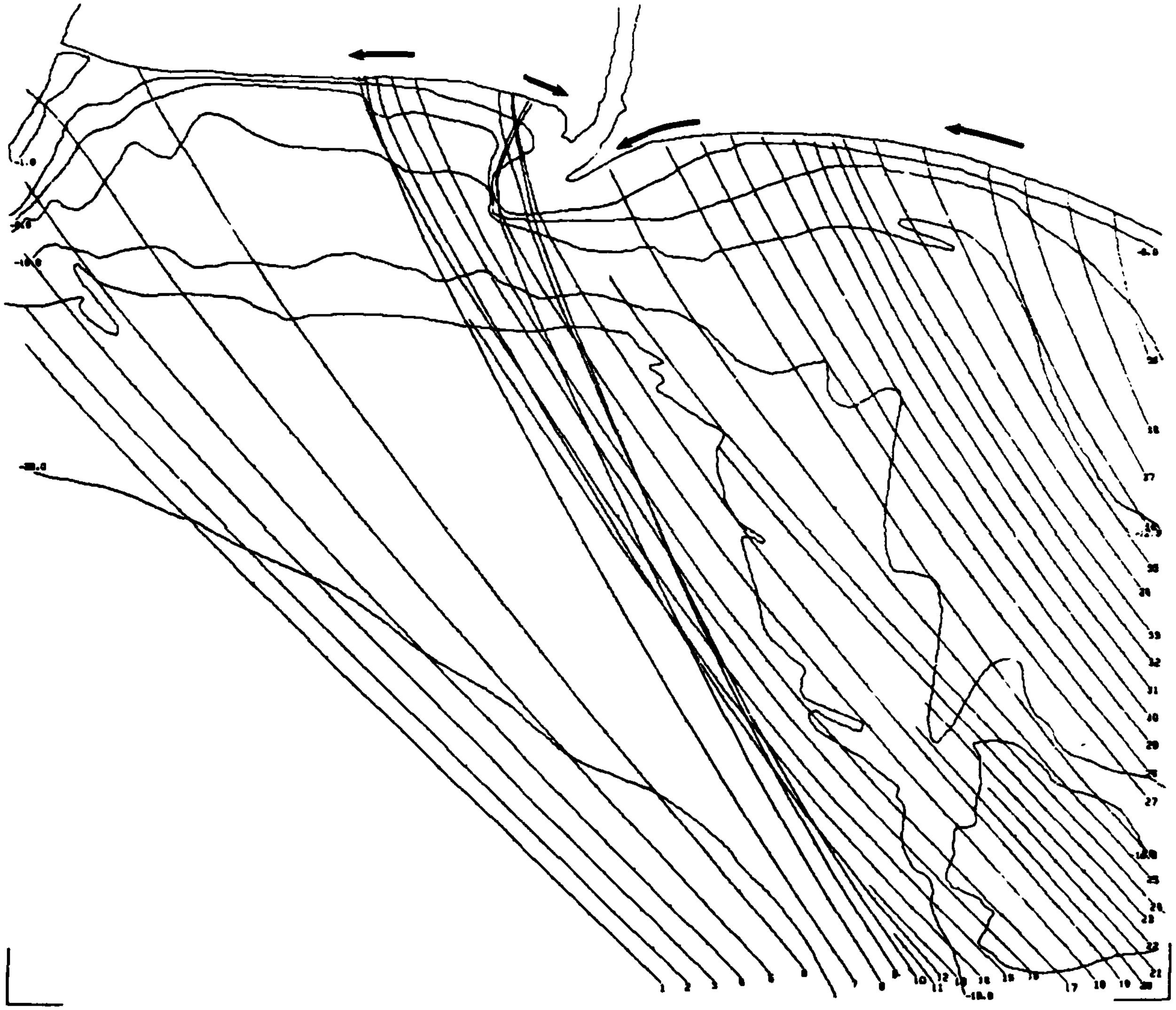


FIG. 9a



PI-1921 T4.90

FIG. 9b

WAVE PERIOD= .000 SECS
DEEPWATER AZIMUTH= 90.0 DEGREES
DATE PLOTTED: 05/14/78
DEEPWATER WAVE HEIGHT= 1.00 FEET

0 CONTOUR AT MLW
RELATIVE WATER LEVEL= 0.00 FEET
MAP DATE: 1921

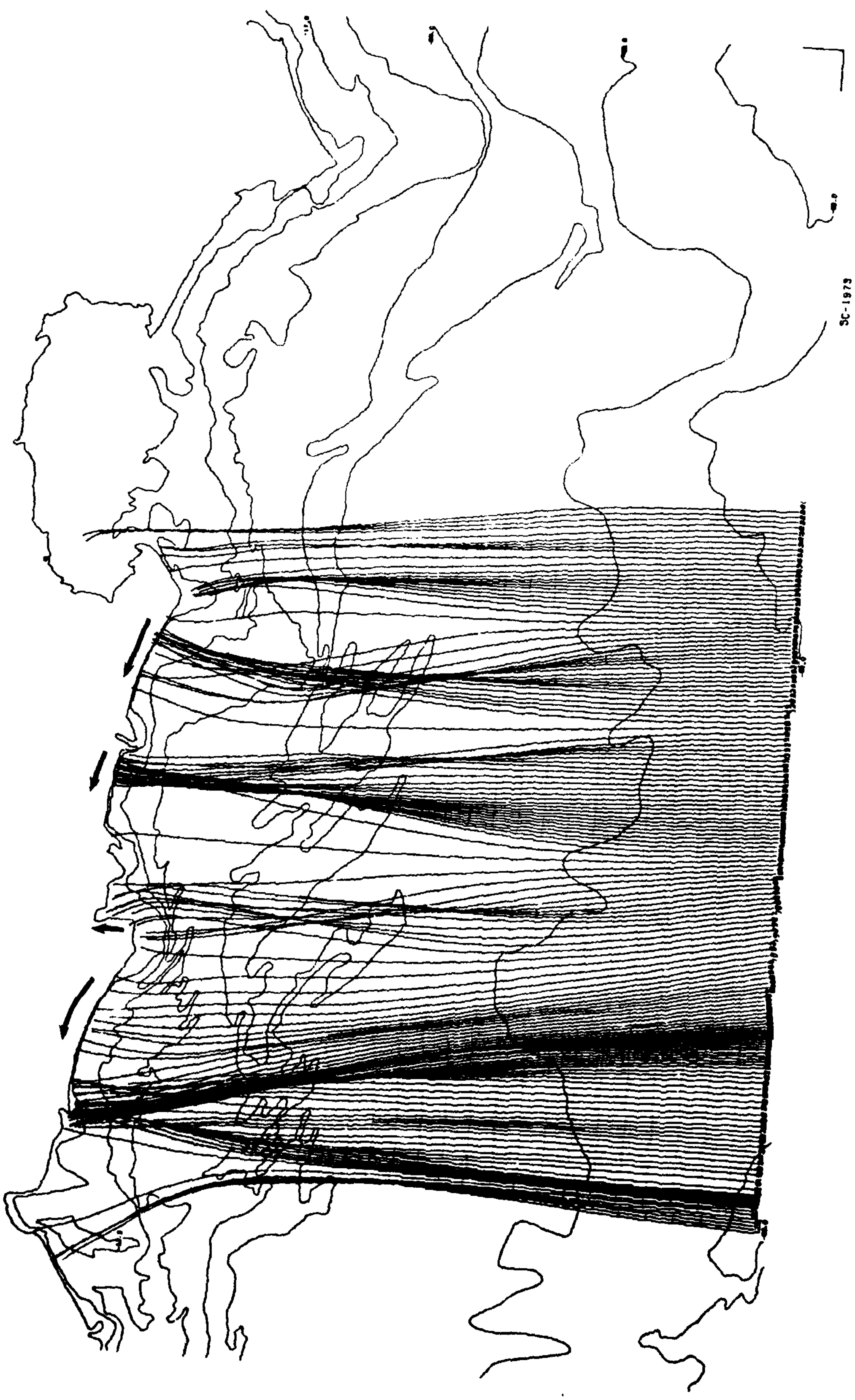


FIG. 10

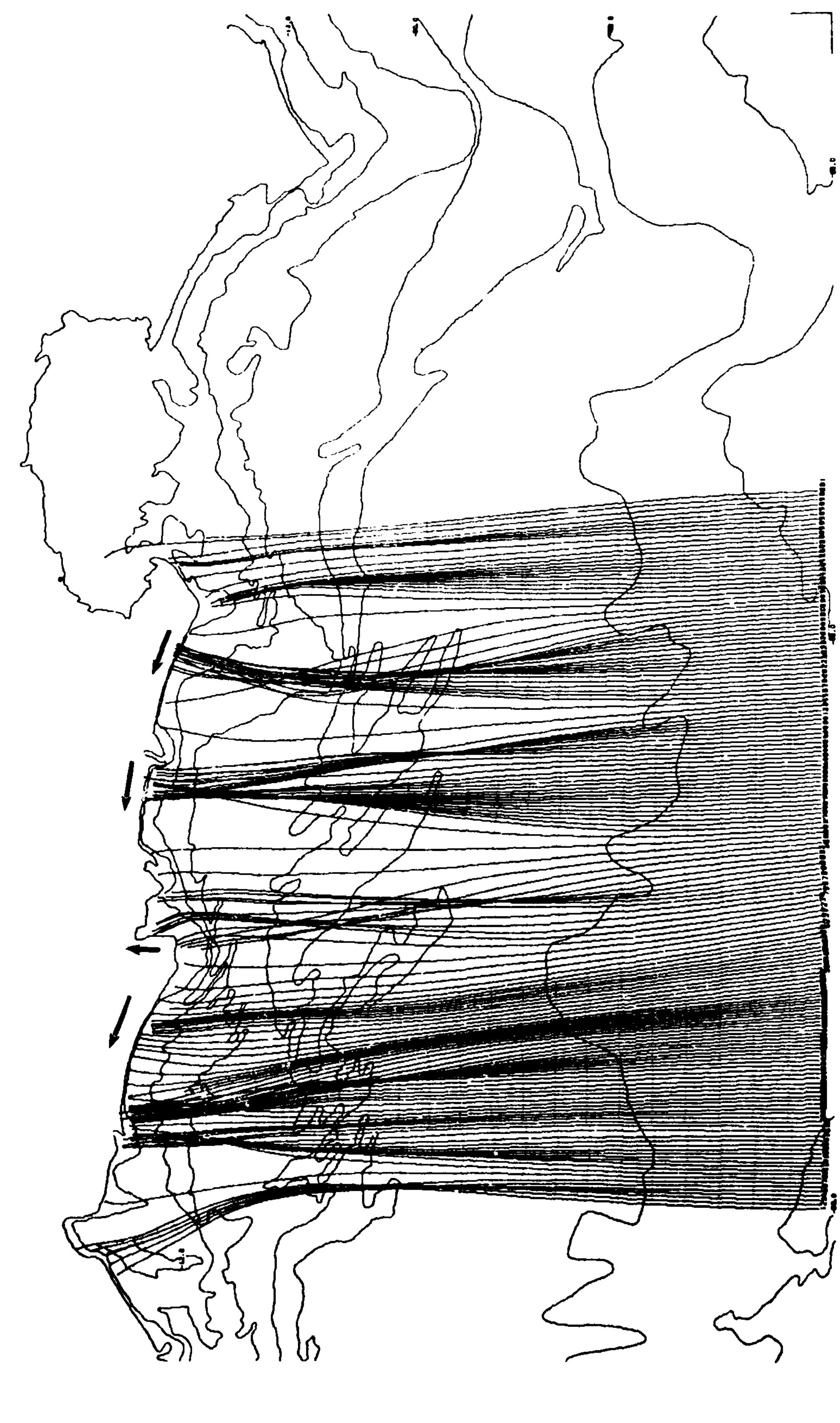


FIG. 11

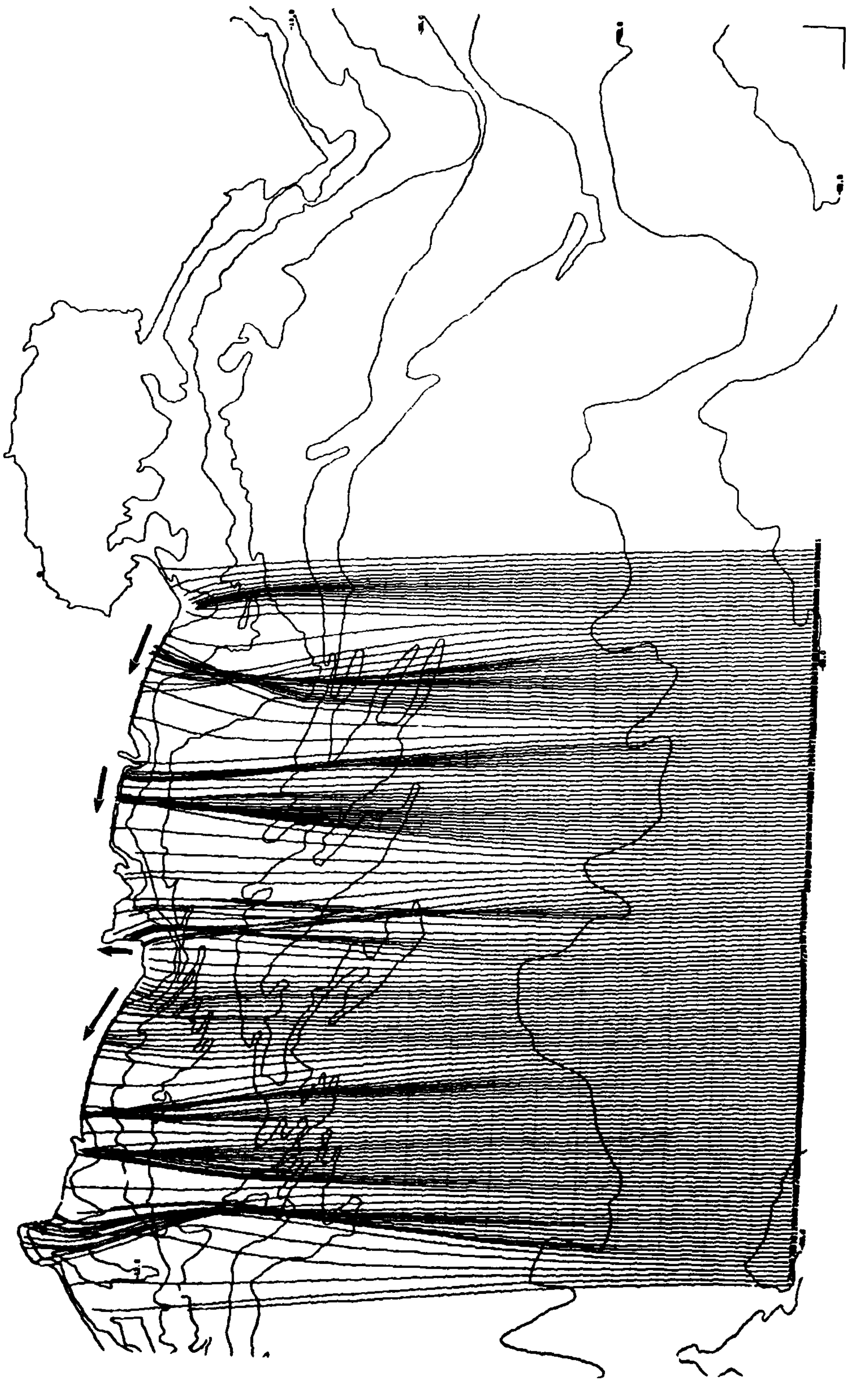


FIG. 12

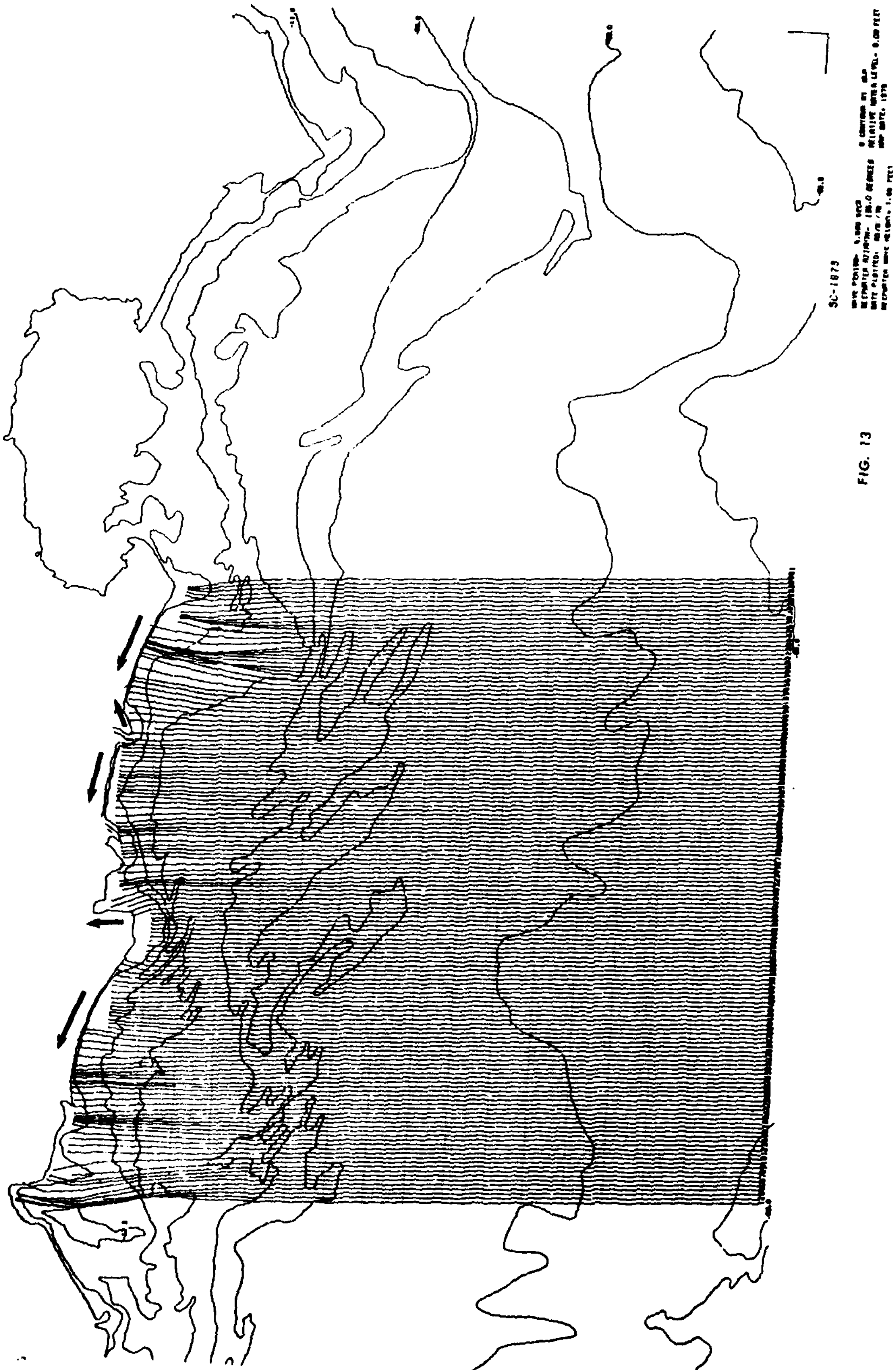


FIG. 13

FIG. 14a

PI-1963 T10A135

WAVE PERIOD= 10.000 SECS
DEEPWATER AZIMUTH= 135.0 ; SPEED
DATE PLOTTED= 06/16/78
DEEPWATER WAVE HEIGHT= 1.00 FEET

0 CONTOUR AT MLW
RELATIVE WATER LEVEL= 0.00 FEET
MAP DATE: 1963

PI-1921 T10R135

WAVE PERIOD= 10.000 SECS
DEEPWATER AZIMUTH= 135.0 DEGREES
DATE PLOTTED: 05/14/78
DEEPWATER WAVE HEIGHT= 1.00 FEET

0 CONTOUR AT MLW
RELATIVE WATER LEVEL= 0.00 FEET
MAP DATE: 1921

FIG. 14b

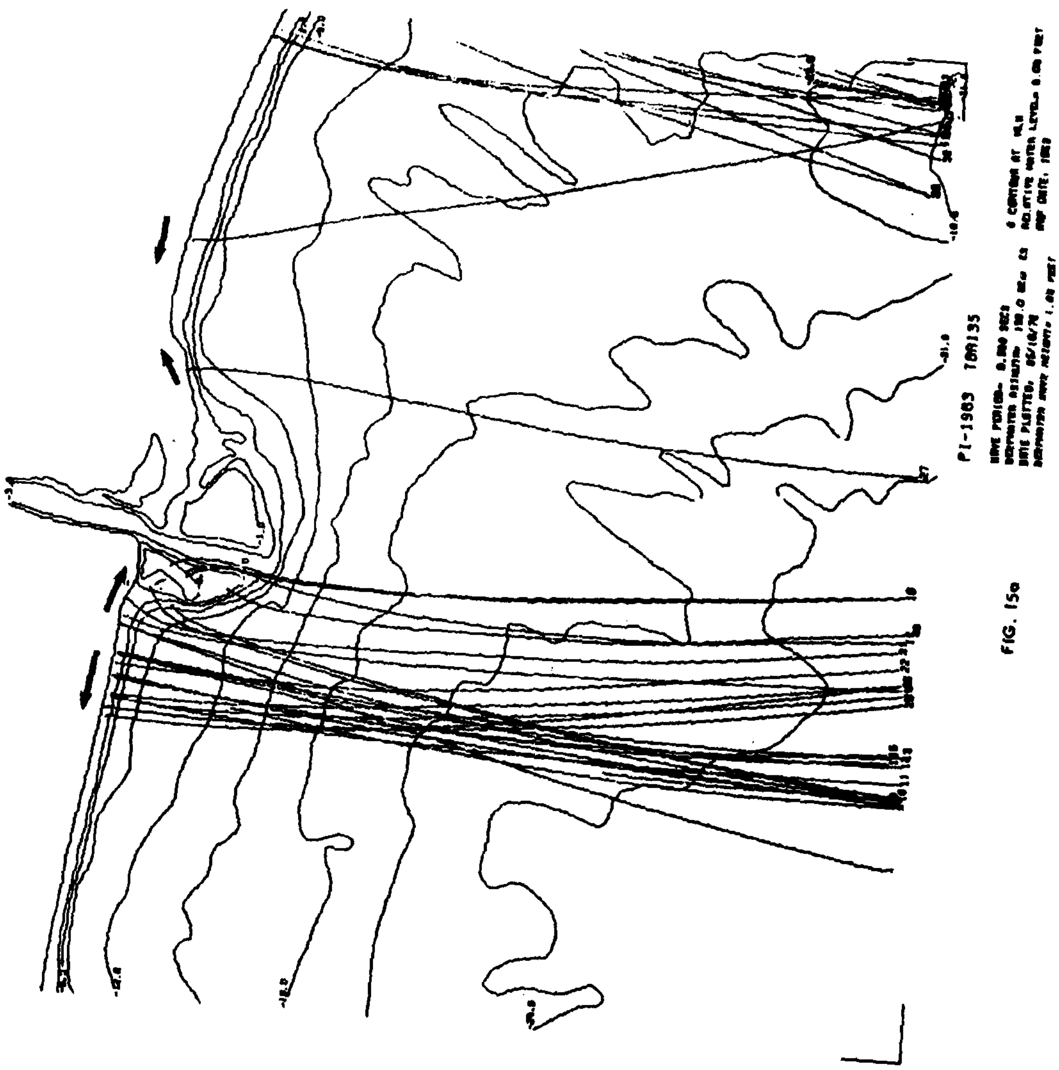


FIG. 15a

PI-'921 T8A135

FIG. 15b

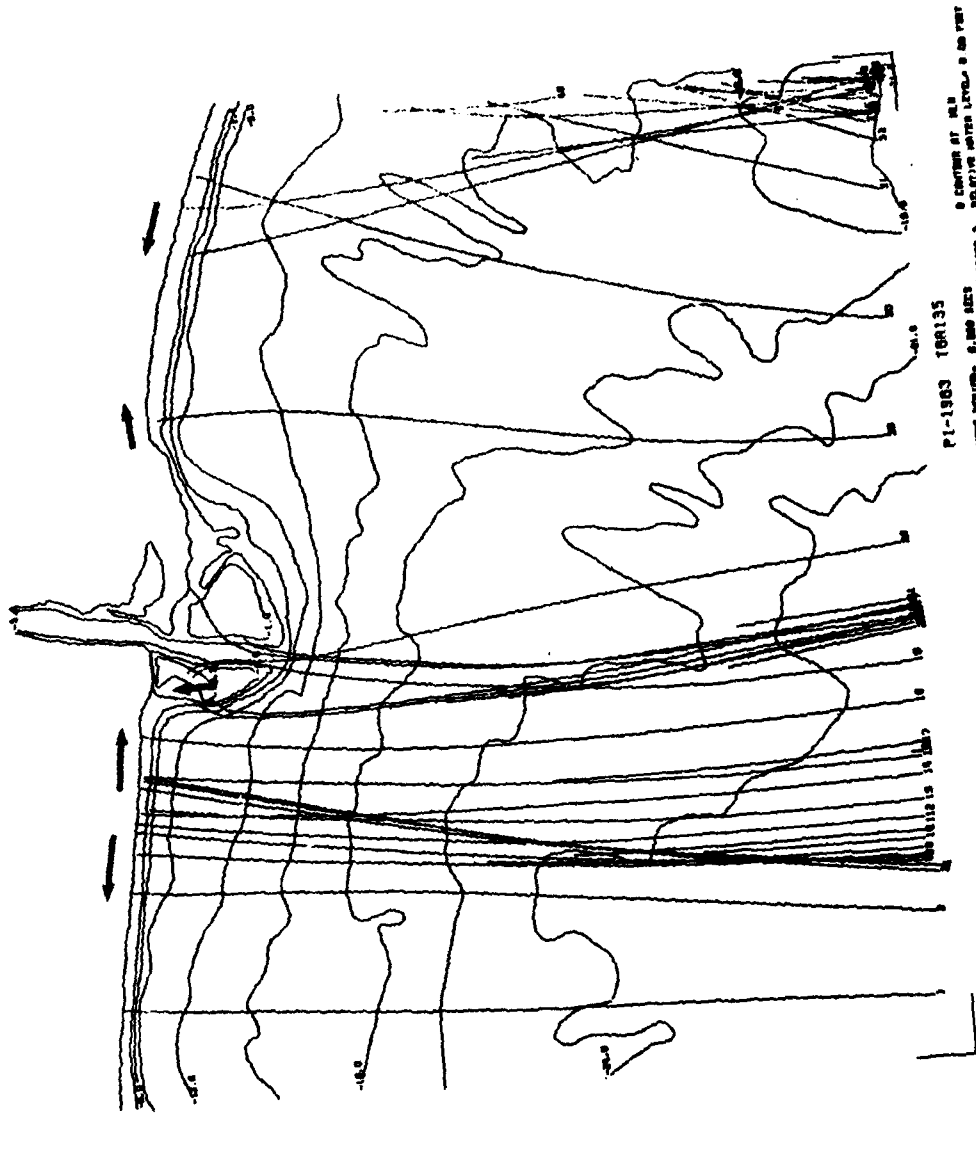
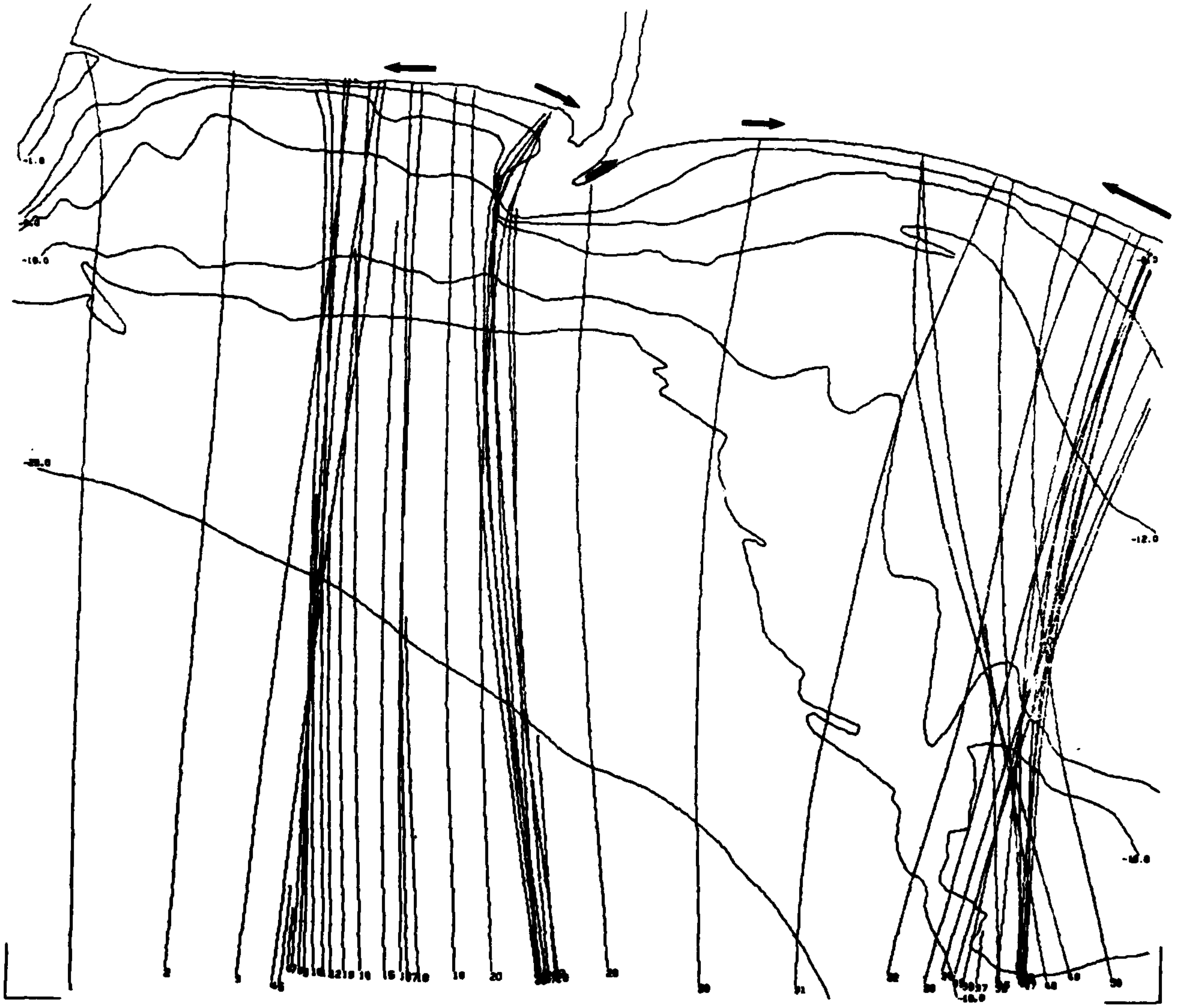


FIG. 16a



PI-1921 T8R135

FIG. 16b

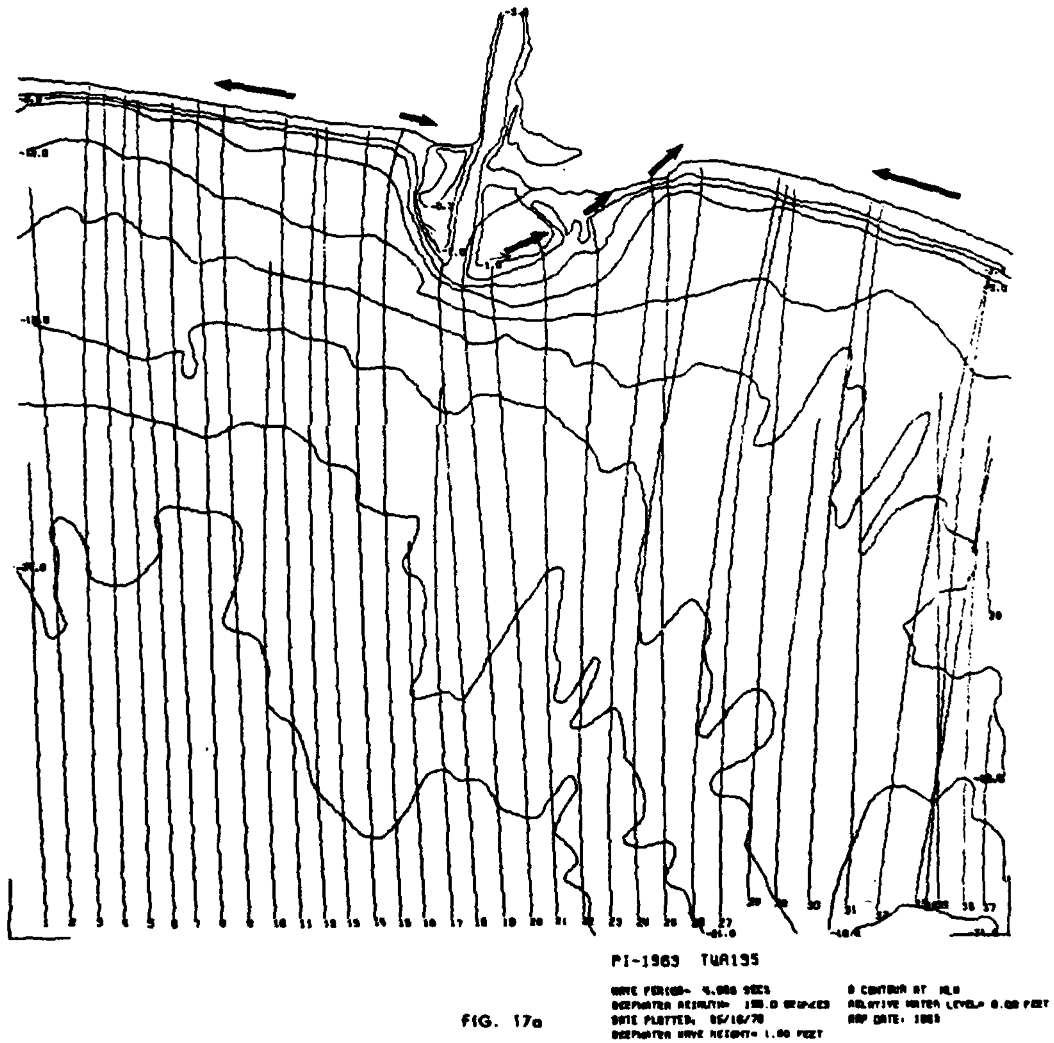
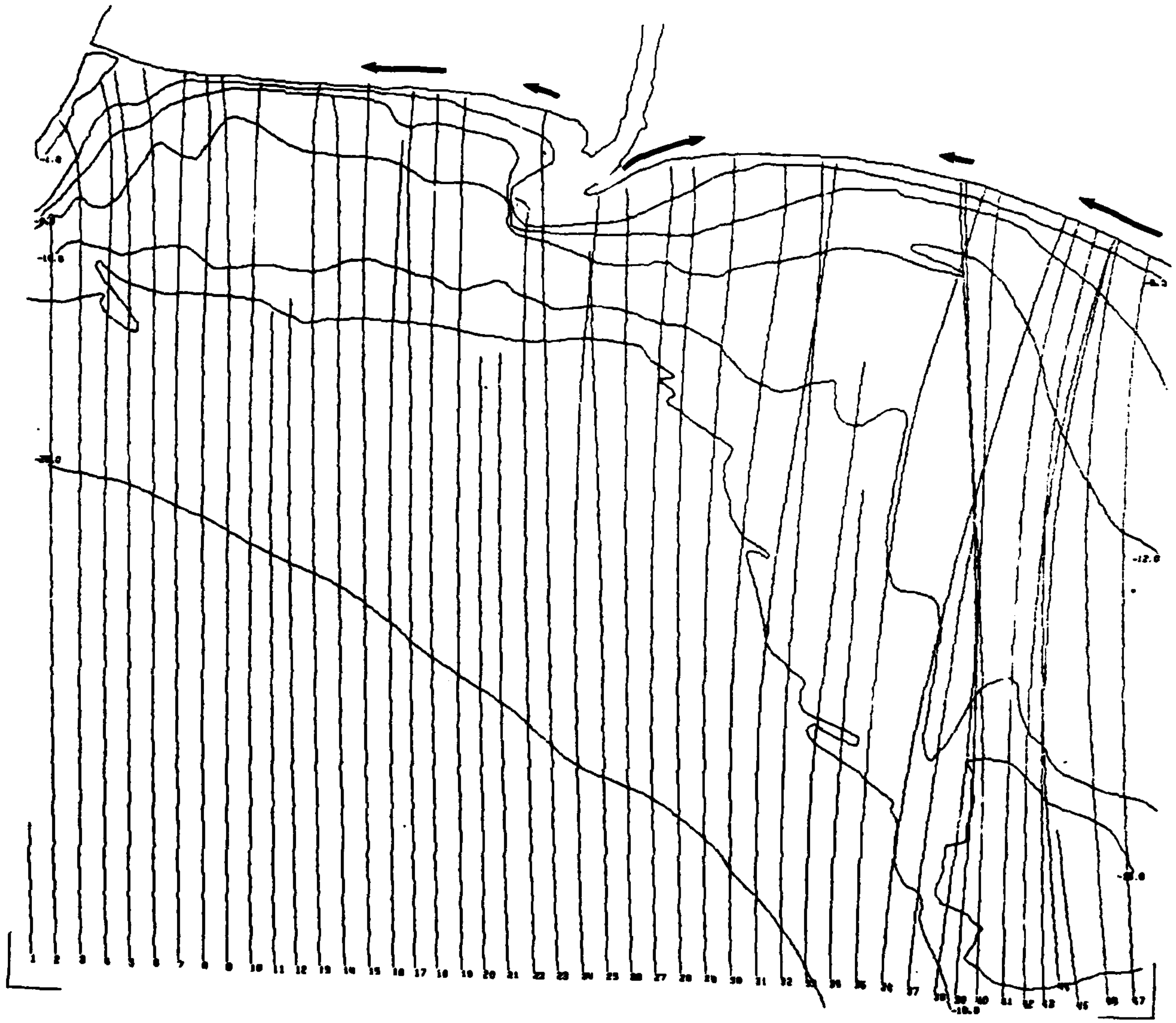


FIG. 17a



PI-1921 THA135

WAVE PERIOD= 4.000 SECS
DEEPWATER AZIMUTH= 135.0 DEGREES
DATE PLOTTED: 05/14/78
DEEPWATER WAVE HEIGHT= 1.00 FEET

0 CONTOUR AT MLW
RELATIVE WATER LEVEL= 0.00 FEET
MAP DATE: 1921

FIG. 17b

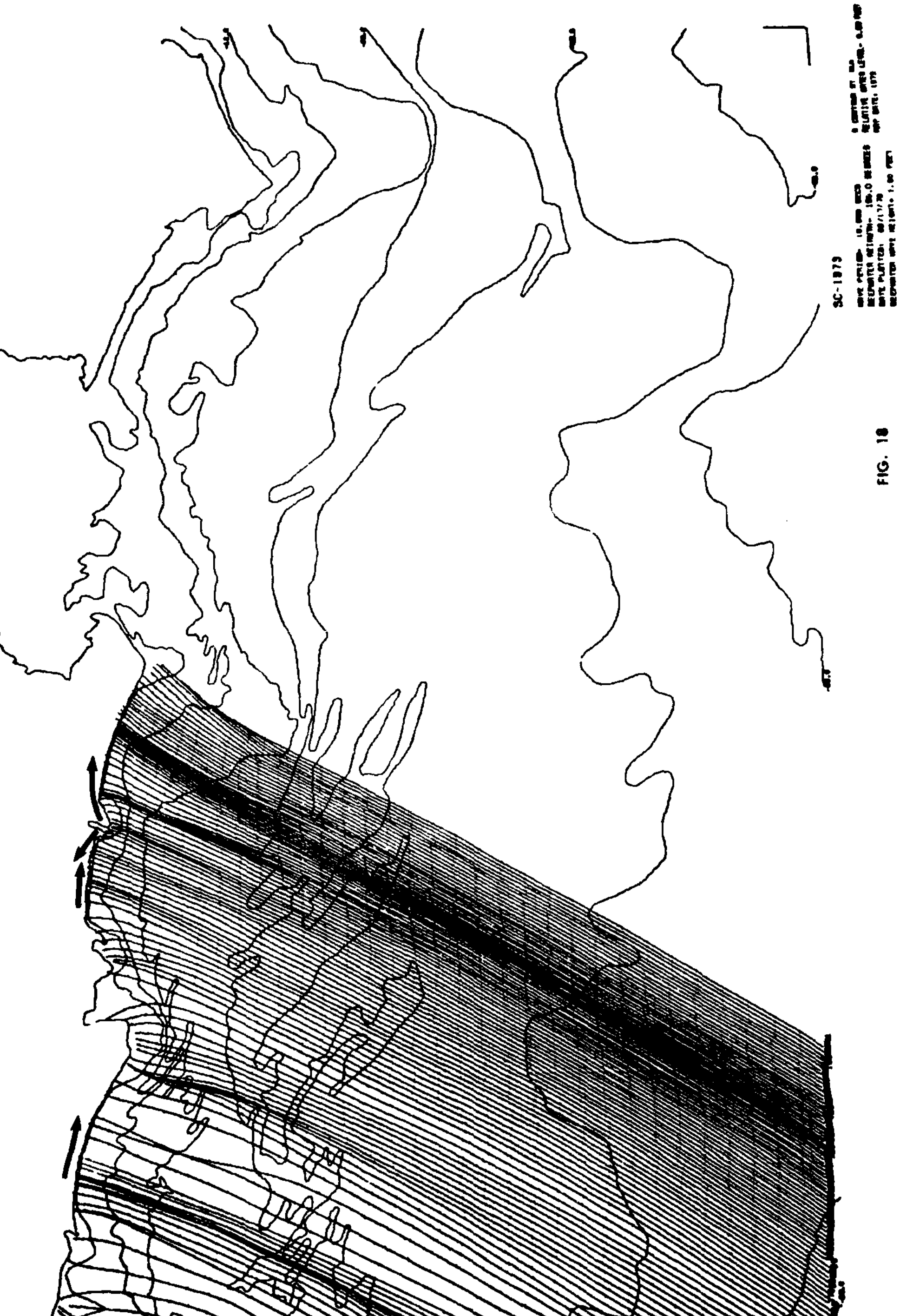


FIG. 18

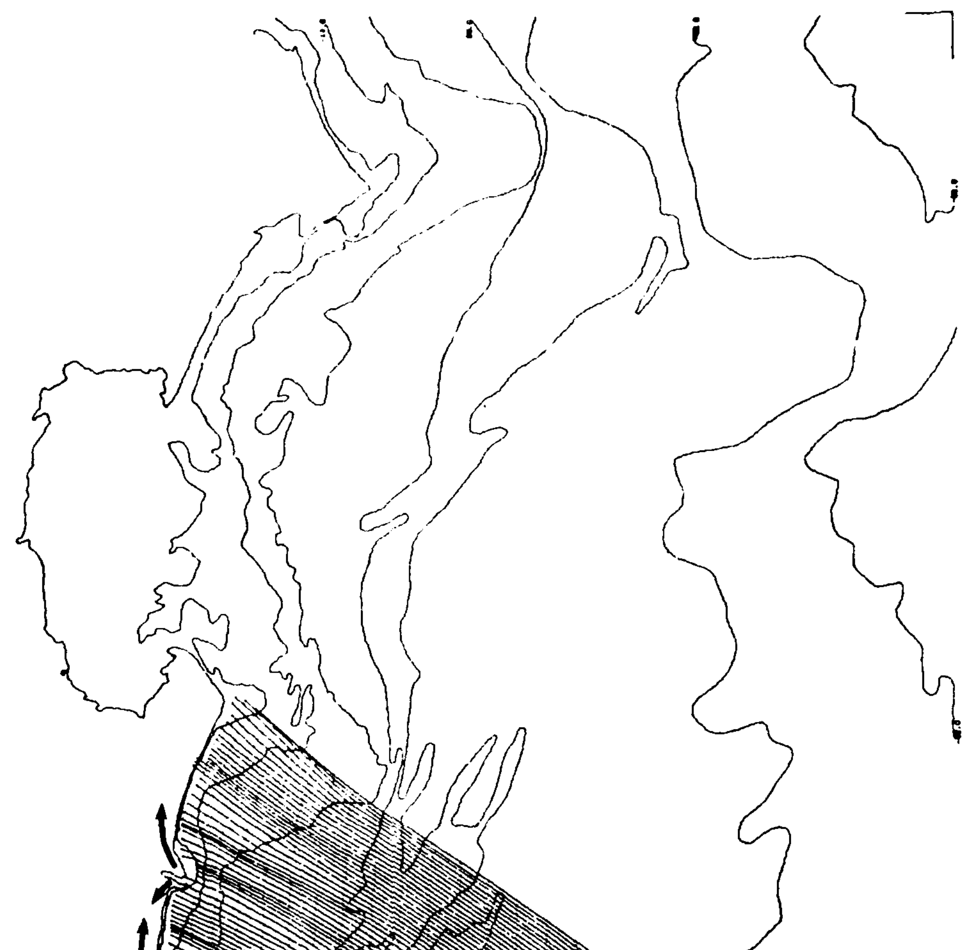
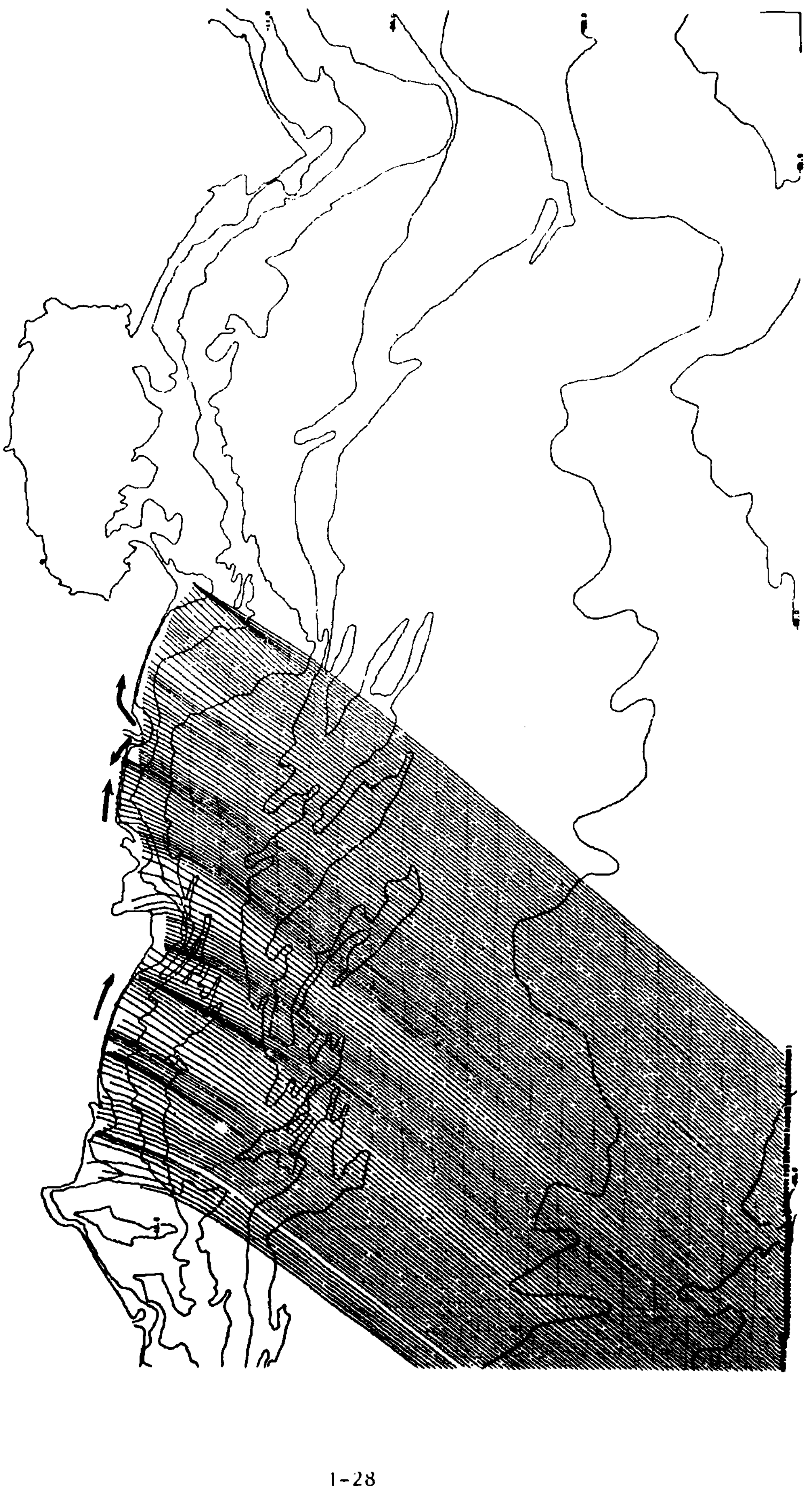


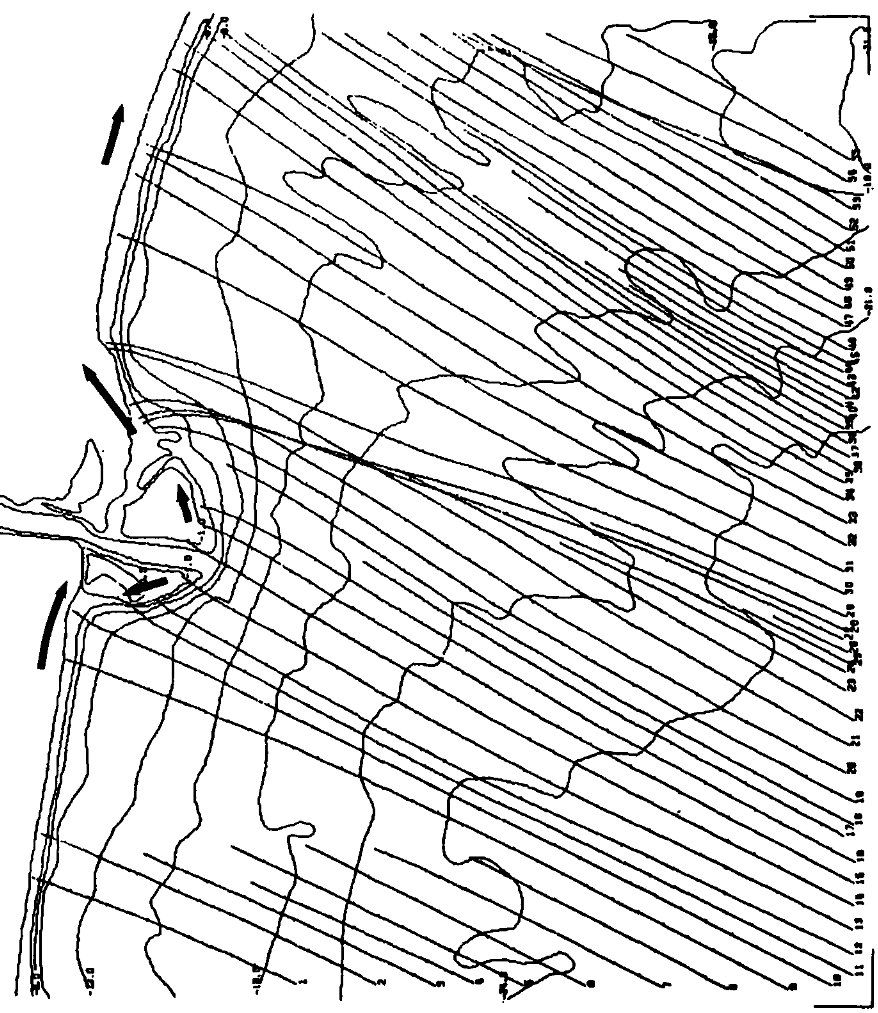
FIG 19



SC-1073

FIG. 20

FIG. 2.



PI-1963 TIDA180
WAVE PERIOD- 10.000 SECS
DEEPWATER WAVE HEIGHT- 1.00 FEET
0 CONTOUR AT MLW

FIG. 22a

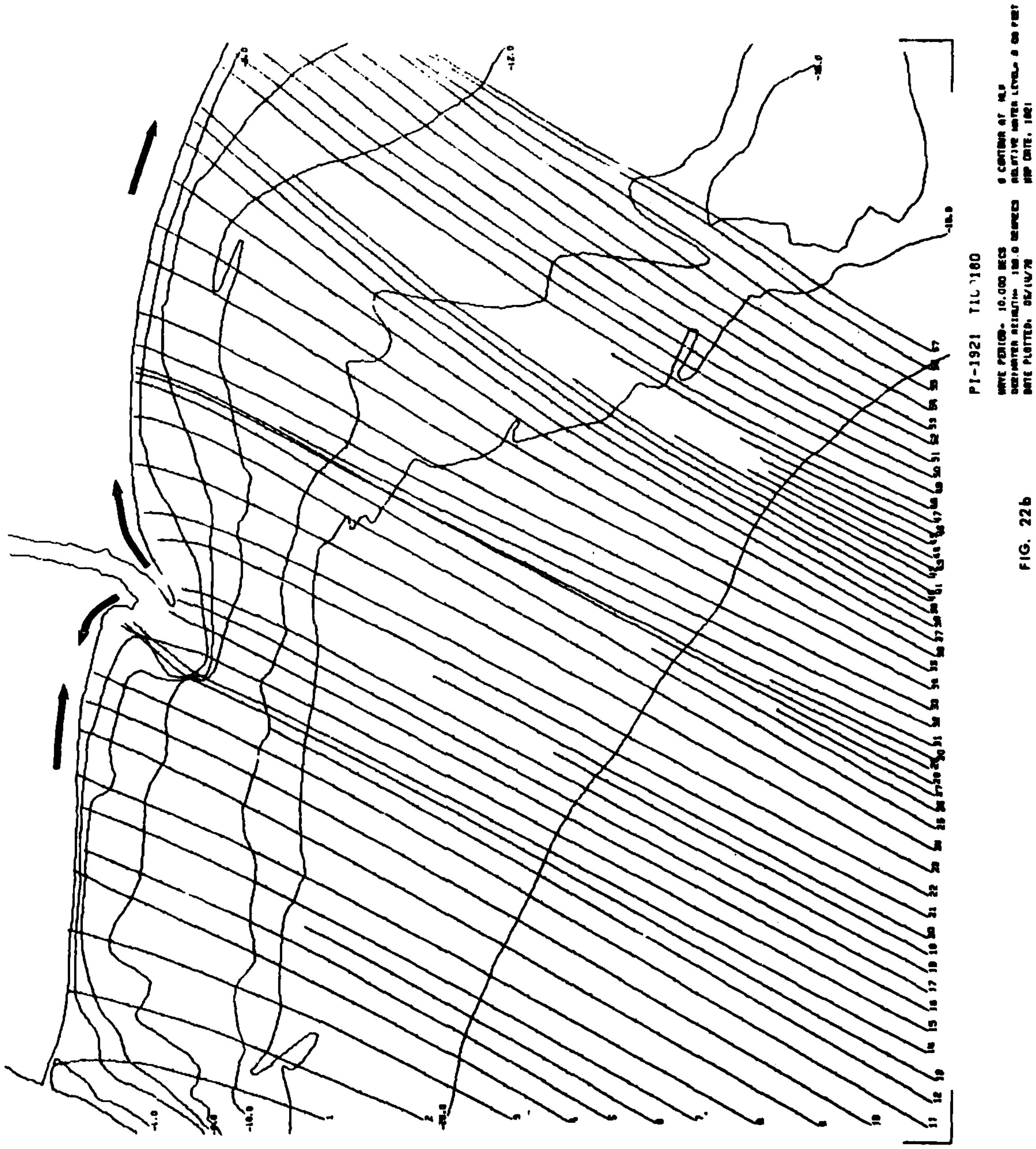


FIG. 22b

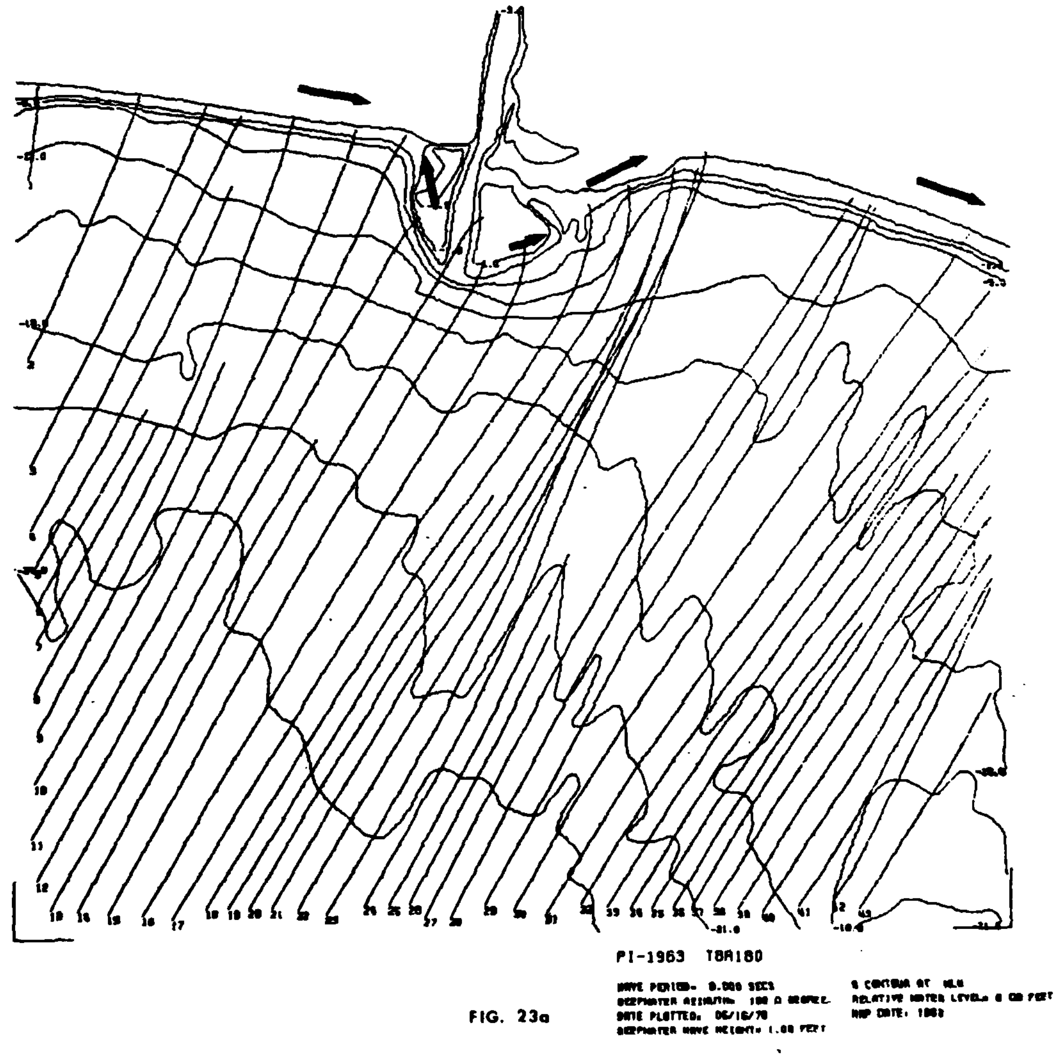


FIG. 23a

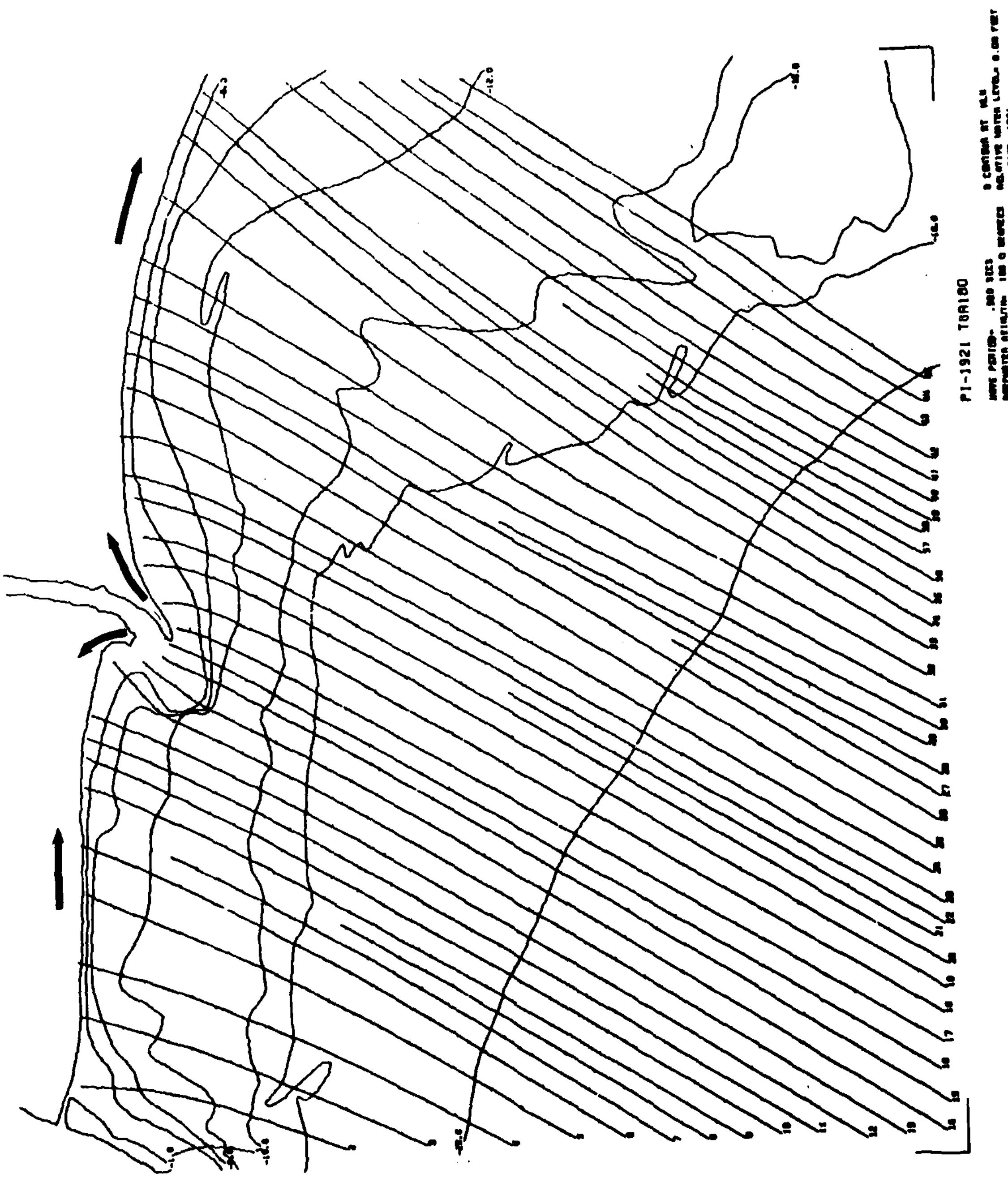


FIG. 23b

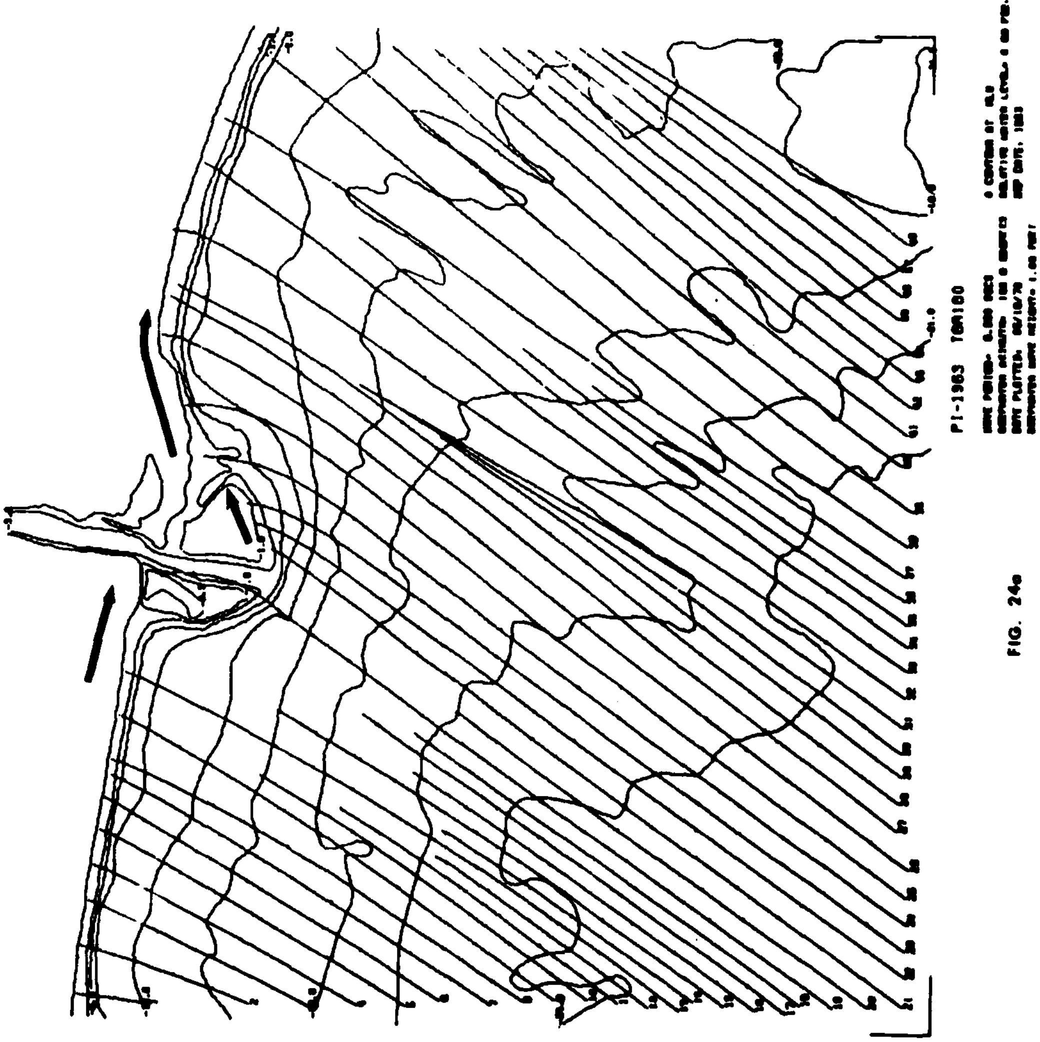


FIG. 24e

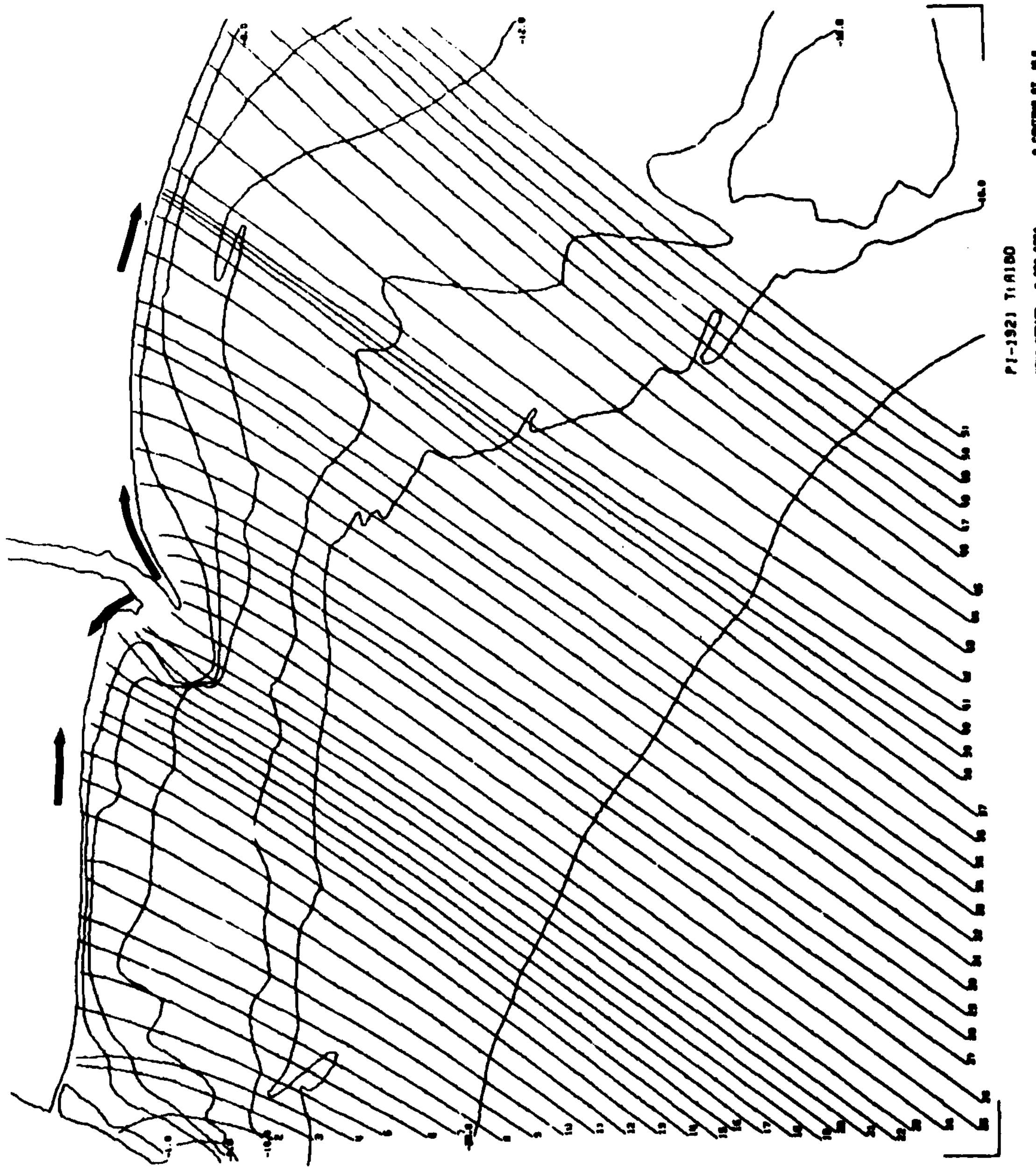


FIG. 24b

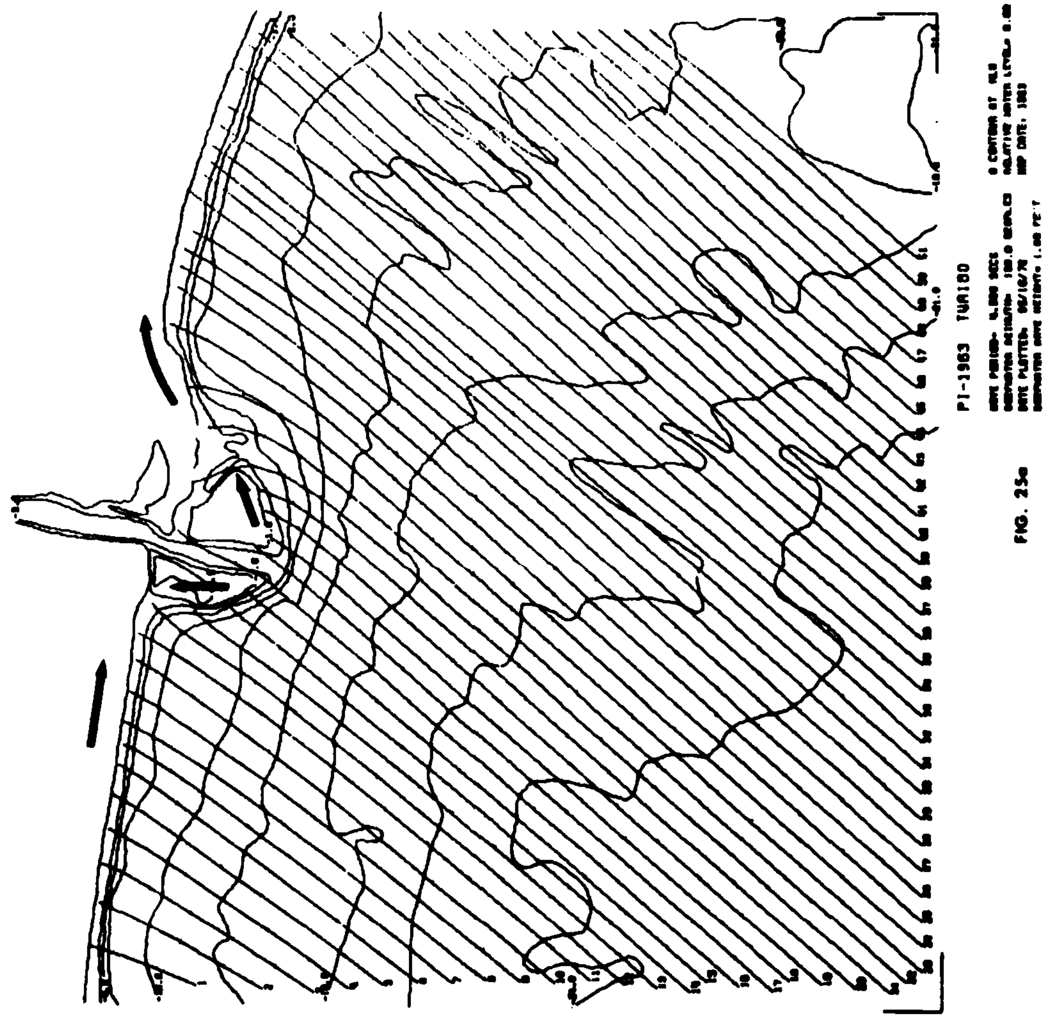


FIG. 25a

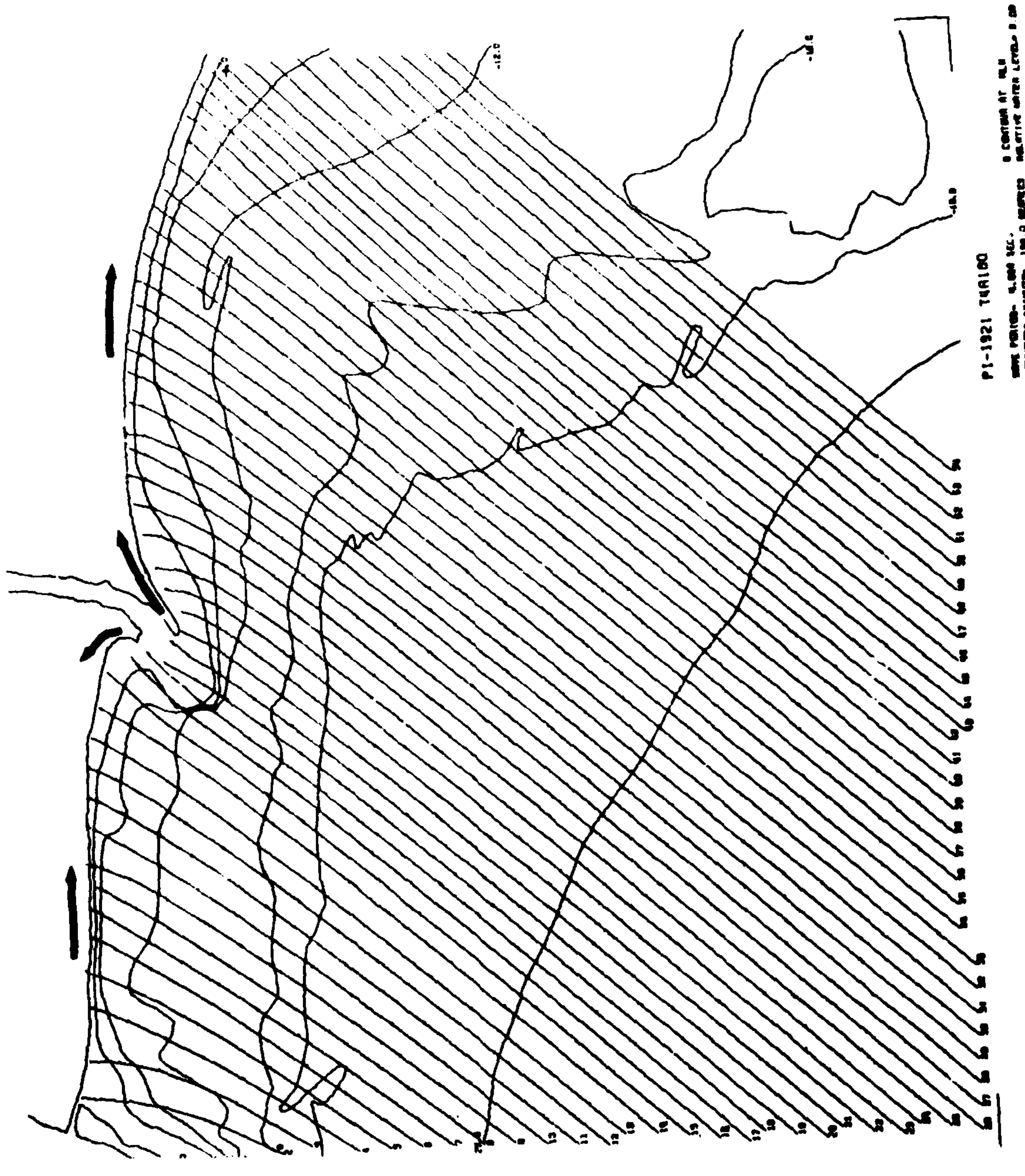


FIG. 25b

APPENDIX II

REFRAC--User's Guide

PROGRAM DESCRIPTION

Module Description

REFRAC is divided into a MAIN routine and several subroutines: RAYCON, REFRAC, CURVE, DEPTH, HEIGHT, REFDIA, ENERGY, BOTTOM and SORT1. The subroutine ENERGY is similar to the subroutine used by Colonell and Goldsmith (personal communication) for calculations of wave power and energy.

MAIN Routine. - This routine reads the input wave parameters such as initial wave height, period, direction and starting grid coordinates. Calculated refraction coefficients need be supplied if the wave starts in shallow water. Controlling program parameters such as window specifications, number of wave rays and so on are also read. Output includes a title page listing the input parameters for quick referral and comparisons between sets of rays. The shoreline, depth contours and plot title information are plotted at this time. Calculations of deep water wave celerity and length and the depth at which refraction will begin are performed. Further calculations include printing and plotting intervals based on a time step. Time was chosen as the independent variable in the governing equations because in deep water where effects of refraction are small, the celerity and, therefore the distance, between two points decreases. This coincides with the area in which the greatest detail is desired. The first subroutine called in this program is BOTTOM which sets up the depth grid for later calculations. Nested loops control the number of sets of rays and the number of rays per set to be analyzed. In the inner loop, control is passed to subroutine RAYCON which cal-

culates each ray's path across the depth grid.

Subroutine RAYCON. - RAYCON controls each individual ray as it progresses across the grid. Initially, the wave is advanced one step and the depth calculated (from DEPTH subroutine) at this point. If the depth is greater than one-half the deep water wave length, deep water conditions exist signifying no changes in the wave. Printing and plotting options are then checked. The above steps are repeated until transitional water depths are reached, that is, until the wave feels bottom. Wave height and boundary positions are continuously checked for breaking wave or out of bound conditions. As the wave progresses through transitional water depths, the ray begins to refract. RAYCON repeatedly calls CURVE, REFRAC, and HEIGHT to calculate the curvature, step length and wave height resulting from increased refraction and shoaling. The ray may be stopped for a variety of reasons: there is no convergence in the calculation for curvature, the wave breaks, the ray reaches one of the boundaries, the maximum number of points calculated has been exceeded, or the incremental distance between steps is less than the minimum specified. As mentioned previously, RAYCON controls the printing and plotting for each ray. At user-determined intervals, a tick mark is plotted on the wave ray, and corresponding wave information, denoted by an asterisk, is printed. Subroutine ENERGY is called before each line is printed in order to calculate wave power and energy at that point. The boundaries for a more detailed window are calculated if a window has been specified in the input parameters. As a ray crosses these boundaries, values are generated and stored on disk to be used as input data into a later, more detailed refraction analysis.

Subroutine REFRAC. - This routine and the following subroutines are called repeatedly after the wave ray has entered transitional water depths. REFRAC calculates the step length which is a function of the wave celerity and time. If the step length is greater than the minimum value specified in the input, the curvature (through CURVE subroutine) and next X,Y coordinates are calculated. The initial curvature is used to project the next point on the ray. A new curvature at this point is calculated and compared to the original curvature, thus giving a better estimate of the position for this point. This process is repeated until the difference between two successive calculations is acceptably small; then the new point is considered fixed. Two conditions of instability can arise. One condition results in the curvature being averaged between solutions; a message is printed to this effect. The other condition results from the failure of the calculations to converge, in which case the ray is stopped.

Subroutine CURVE. - Based on the depth of the water, one of two equations is used to calculate the wave celerity. Five one-thousandths (.005) of the wavelength is the program's boundary between shallow water and intermediate depths. The curvature of the ray is then calculated. The curvature is a function of the ratio between local speed and deep water wave speed, the depth and several depth-related coefficients, plus the azimuth of the ray.

Subroutine DEPTH. - A second degree polynomial fitted locally (instead of on the complete depth grid) provides an accurate method for interpolating depths at intermediate points (Dobson, 1967). The equation is:

$$\text{DEPTH} = e_1 + e_2x + e_3y + e_4x^2 + e_5xy + e_6y^2$$

The local grid system consists of 12 points (Fig. 1) which are filtered through a matrix of weighting terms derived from the relative positions of the data points. This local grid system traces the ray's path shoreward across the depth grid. The six coefficients in the equation result from a summing f the different filtered depths and remain constant within the local coordinate system. Calculation of the curvature and refraction coefficient for a point are based on these six coefficients.

Subroutine HEIGHT. - This subroutine calculates the shoaling and refraction coefficients, which are used in the computation of the local wave height. The shoaling coefficient is equal to the ratio of the group velocity in deep water to local group velocity and therefore dependent on the water depth. The refraction coefficient is determined by the change in separation of wave rays. Dobson (1967) created a separation factor which is a function of wave celerity, azimuth of the ray and the six depth coefficients. As a result, the calculation of the refraction coefficient for the present time step is dependent on the refraction coefficient of the previous time step.

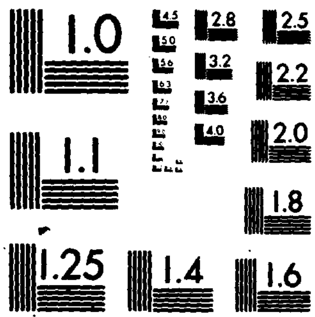
Subroutine REFDIA. - This subroutine plots the X, Y coordinates of the ray as it progresses shoreward. The grid coordinates are multiplied by the length of a grid side to convert them into plot inches before plotting. The data input variable BOUND is subtracted from the deep-end of the y-axis if this part of the plot is not desired.

Subroutine ENERGY. - The equations used in this routine and their derivations may be found in the Shore Protection Manual (Coastal Engineering Research Center, 1973). As part of each printed line of output, the total wave power and energy, the longshore power and direction (left or right) are calculated and printed. Longshore transport

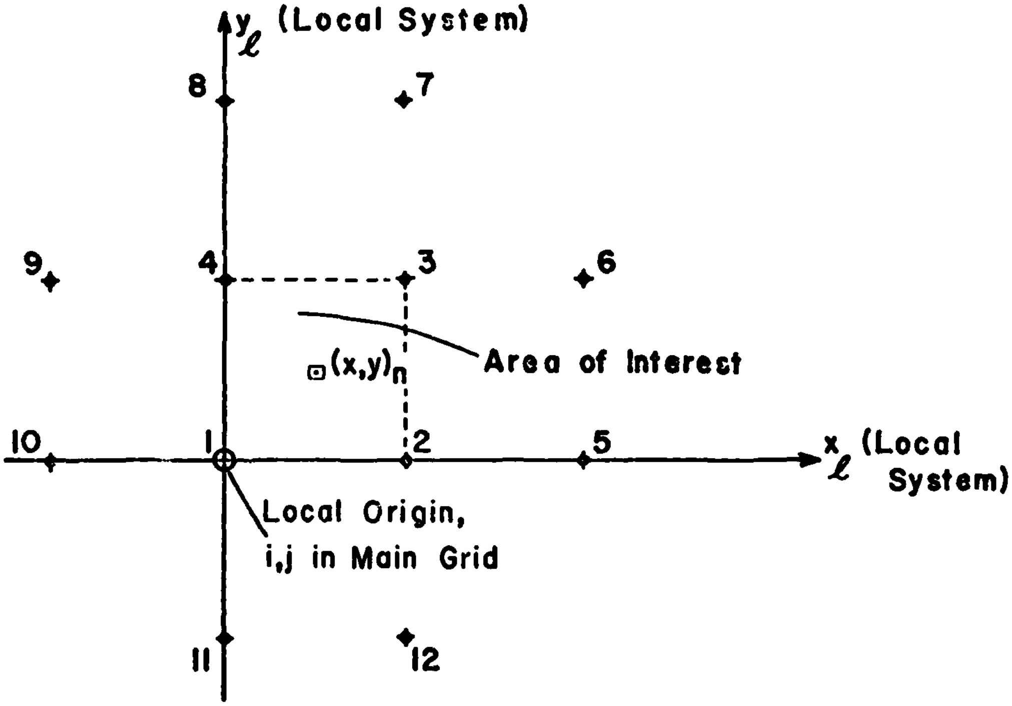
Figure 1. Local grid system used in surface fitting procedure for depth calculations.

AD-A091 913 SOUTH CAROLINA UNIV COLUMBIA COASTAL RESEARCH DIV F/G 8/3
INFLUENCE OF WAVE REFRACTION ON COASTAL GEOMORPHOLOGY-BULL ISLA--ETC(U)
DEC 78 C FICO DAAG29-76-G-0111
UNCLASSIFIED TR-17-CRD ARO-13237.15-GS NL

2 OF 3
AD A091913



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



y_ℓ (Local System)
8
7
9
4
3
6
Area of Interest
$(x,y)_n$
10
1
2
5
x_ℓ (Local System)
Local Origin, i,j in Main Grid
11
12

rates based on wave energy flux and Galvin's (1972) gross longshore transport rates based on breaker height are calculated at the breaker points. These transport rates are in cubic yards per year and the wave energy flux transport rate is further converted to cubic meters per year.

Subroutines BOTTOM and SORT1. - BOTTOM creates an evenly-spaced depth grid from a digitized bathymetric map. A maximum of 20,000 grid points may be generated depending on the spacing interval between grid lines which is user determined. The digitized data includes the X,Y coordinates of the map perimeter and the bathymetric contours and their associated depths. Up to 100 different contours can be digitized.

The digitized data is read and converted into a numeric or character format for the program. As the data is read, two temporary disk files are created. These files store the X,Y coordinates for the shoreline and contours and will be plotted when program control returns to the MAIN routine. The points on the perimeter are read first, and the incremental distances and depths calculated. The depths are computed from the straight-line slope formula. These calculations occur between two corners of the map unless contours cross this section of the perimeter, in which case calculations occur between the corner and the first contour; between contours (if more than one crossed the perimeter); and the last contour and far corner. Upon completion of the perimeter, the coordinates of the contours are read and converted into the proper format. After the digitized tape is read, the tape is rewound and the SORT1 routine called.

Subroutine SORT1 written in Assember language, links a system utility sort to REFRAC. The depths and their coordinates are sorted

to build the desired depth grid. Note that, at this point, the only depths are the incremental depths along the perimeter and the depths located at the contours. After the sort is completed, BOTTOM is re-entered and the remaining depths calculated.

Grid depths are calculated parallel to the y-axis, one grid line at a time. The distance between two points on two contours or a contour and perimeter with the same x-coordinate is completed. The depth distance between these two points divided by their distance determines the slope which is used to calculate the incremental depths between the two points. Because of the method of interpolation described, the y-axis should be drawn as perpendicular to the contours as possible.

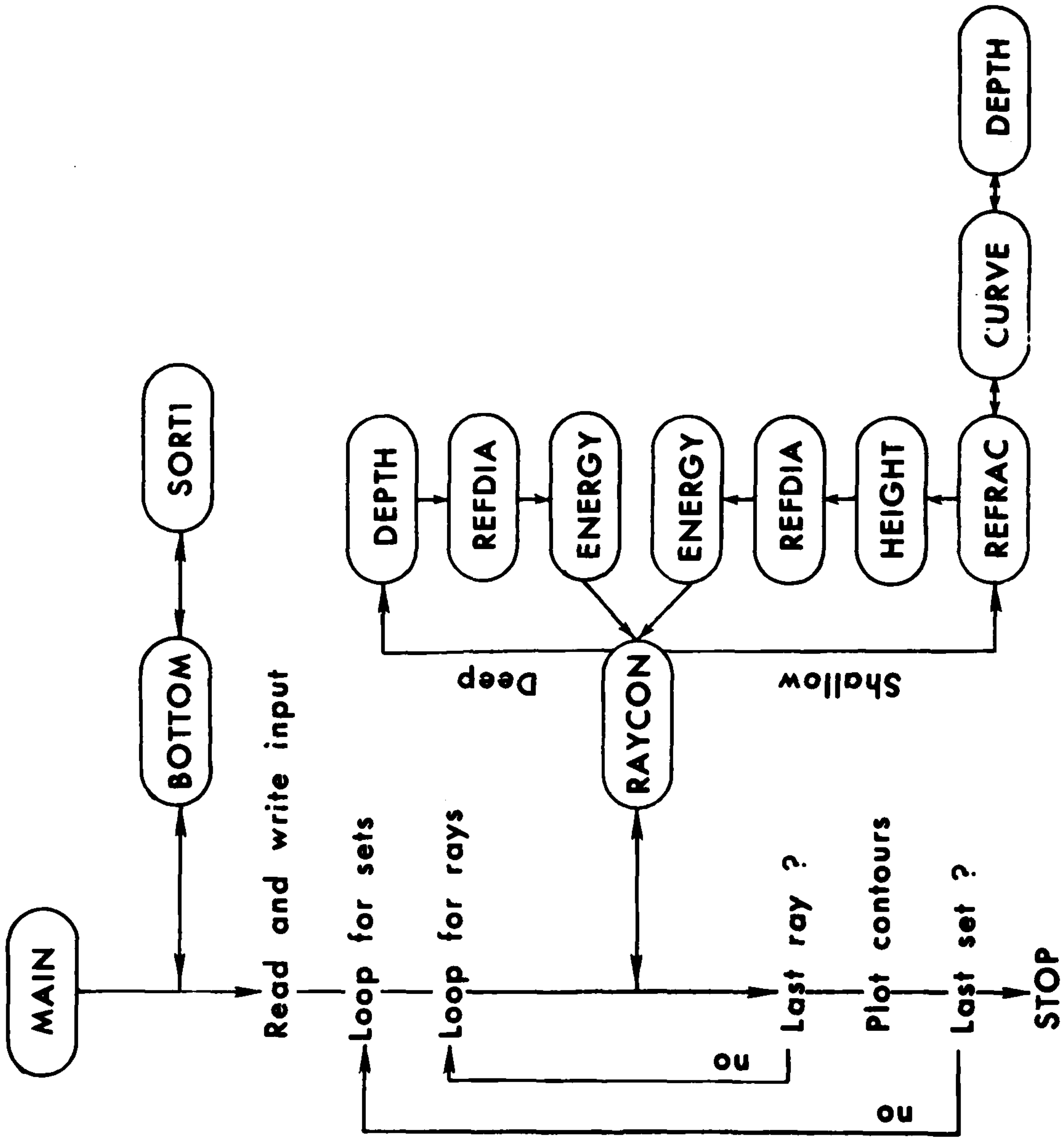
Upon completion of the grid, program control returns to the MAIN routine and refraction calculations as described in the previous subroutines begin. Fig. 2 is a generalized diagram of the flow of control in the program REFRAC.

Output Description

REFRAC has two types of output to describe ray refraction. The first, printed information includes a title page per set of rays. Title of the area being analyzed and date of analysis are printed on top of the page. An echo print of all input parameters allows a quick referral when comparing sets of rays. The date of the hydrographic chart and its units of measurement are also printed.

Information on individual rays is printed next. At the start of a ray, a variable GRINC is calculated and printed. GRINC is the deep water step length expressed as a fraction of the grid square and should equal approximately .5. Calculation of GRINC is further discussed in the section on PROGRAMMING CONSIDERATIONS (Determination of Input Param-

Figure 2. Program flow.


MAIN
BOTTOM
SORT1
Read and write input
Loop for sets
Loop for rays
RAYCON
Deep
Shallow
DEPTH
REFDIA
ENERGY
ENERGY
REFDIA
HEIGHT
REFRAC
CURVE
DEPTH
Last ray ?
no
Plot contours
Last set ?
no
STOP

meters). Points along the ray are printed at a user specified interval. Asterisks printed beside the point number correspond with tick marks plotted perpendicular to the ray orthogonal. Point information includes: location of point on the grid, azimuth of the ray, water depth, length, speed and height of wave, refraction and shoaling coefficients, bottom and mid fluid particle velocities, total wave energy and power, the longshore component of power and direction (left or right as the observer faces the ocean). If the wave breaks, the longshore energy flux factor and longshore transport rates are printed. For convenience, the transport rates are converted into metric units. Also, the gross longshore transport rate as derived by Galvin (1972) is printed.

The second type of output is a plot of the refracting rays as they travel shoreward. Plot output includes the digitized shoreline and bathymetric contours. Wave orthogonals or rays (lines parallel to the direction of wave propagation) are plotted with perpendicular tick marks. Title information on the plot includes: the period and deep water wave height and azimuth, date of hydrographic chart, date of plot, water level height of chart and relative water depth of plot to chart.

Input Description

Card input formatting. - Input values are of three types: integer (I) - numeric values without a decimal point; floating point (F) - real numeric values which include a decimal; and alphanumeric (A) - alphabetic or numeric. A field refers to the columns of a punch card where a value is to be found. Integer and real values are to be right-justified; that is, punched in the columns furthest to the right in their particular field. Alphanumeric data should be left-justified.

Blank data fields are interpreted as zeros by the program. The number in parenthesis following the variables description are suggested values.

Card Sequence:

	Columns	Variable	Description
Card #1	1-40	ITITLE (A)	Title of wave refraction analysis
Card #2	1-5	FAC (F)	Size of plot desired relative to original chart.
Card #3	1-4	DATE1 (A)	Year of hydrographic chart soundings.
	7-18	MEAS (A)	Units in which depth of chart is expressed.
	21-24	W (A)	Water level chart was sounded at (e.g. MLLW, MLW LSL, MHW, MHHW).
Card #4	1-5	MI(I)	Number of grid lines in X-direction.
	6-10	MJ(I)	Number of grid lines in Y-direction.
	11-15	LIMNPT (I)	Maximum number of steps to be calculated for a ray (4000).
	16-20	NPRINT (I)	Printing interval (10).
	21-30	GRID (F)	Number of feet (from hydrographic chart) that equal the length of a grid square side.
	31-40	DCON (F)	Conversion factor for depth values to feet.
	41-50	DELTAS (F)	Minimum step length, expressed as a fraction of a grid square (.002).
Card #5	1-10	BOUND (F)	Number of inches to be subtracted from deepwater end of plot.

	11-20	SCX (F)	Length of a grid square in inches.
	21-30	XSG (F)	X-coordinate of lower left corner of window. Set equal to MI if window is not desired.

Note: If window is not desired, remainder of card is left blank.

	31-40	YSG (F)	Y-coordinate of lower left corner of window.
	41-50	SCNV (F)	Magnification of window.
	51-60	DGXL (F)	Length of window (x-direction) expressed in plot inches.
	61-70	DGYL (F)	Height of window (y-direction) expressed in plot inches.
Card #6	1-5	NOSETS (I)	Number of sets of rays to be processed.

Note: Repeat the following cards if more than one set of rays is to be processed.

Card #7	1-5	LPLOT (I)	Number of steps between plot points on a ray (10).
	6-10	NORAYS (I)	Number of rays in a set (Maximum 400).
	11-20	T (F)	Wave period for a set of rays (seconds).
	21-30	HO (F)	Deep water wave height (feet).
	31-40	SK (F)	Shoaling coefficient for first time step.
	41-50	SK1 (F)	Deep water shoaling coefficient (usually 1).
	41-60	THI (F)	Clockwise angle between north on map and y-axis of grid.
	61-70	STAZ (F)	Deepwater azimuth of a set of rays.
	71-80	UNIT (F)	Timestep

Card #8	1-5	ISP (I)	Sets print option on check depth. =-1, information printed and processing of ray continued. =0, no check depth. =+1, information printed and processing of ray stopped.
	6-10	LCK (I)	Starting position for set of rays. =0, rays start in deep water. =+1, rays start in shallow water.
	11-20	WPI (F)	Number of wave periods between tick marks on a ray.
	21-30	CKDEP (F)	Check depth, ray information will be printed for step nearest this depth.
	31-40	DF (F)	Factor to convert depth values from one water surface datum to another. The factor will be added to the depth values. If not needed, leave blank.
	41-45	IWR (I)	Specifies if starting coordinates for a set of rays is the same as a previous set. =0, new wave information to be read off of cards or disk. =+1, wave information same as previous set.
	46-50	PD (F)	Depth at which printing of ray information will begin. If left blank, PD will equal first depth value on grid.
	56-65	YFA (F)	Factor added to the y-coordinate of the starting point of a ray in order to decrease the amount of deep water region the wave travels over, thereby decreasing computation time.

Card #9	4-5	IRED (I)	If IWR=0 and the information for card deck #10 resides on disk, set IRED to 25, otherwise leave blank. IRED equals 25 implies that the ray information was generated by a previous run on a smaller scale map through a window and stored on disk.

The following card must be repeated for each ray in a set. (Note: for any set other than the first set, if IWR = 1, these cards are not needed. The information is taken from the previous set.)

Card #10	1-10	X (F)	X-coordinate for starting position of ray.
	11-20	Y (F)	Y-coordinate for starting position of ray.

Note: The following variables are needed if the ray is starting in shallow water, otherwise leave blank.

	21-30	AZIMTH (F)	Azimuth of a ray.
	31-40	RK1 (F)	Refraction coefficient of wave ray at the time step previous to starting location.
	41-50	RK (F)	Refraction coefficient of wave ray at starting location.

Digitized depth input. - This section describes in a step by step format how to prepare a hydrographic chart for digitizing and the digitizing process.

Step 1 - Outline the area of interest. Enclose the area of interest in a rectangular outline. This outline is the perimeter of the grid system which will be generated from the digitized contours. The perimeter should be oriented so that the wave rays travel from deep to shallower water. In other words, the Y-axis is more or less perpendicular to the shoreline or contours. Figure 3 shows the perimeter orienta-

Figure 3. Hypothetical hydrographic chart to be digitized. Contours are in feet.

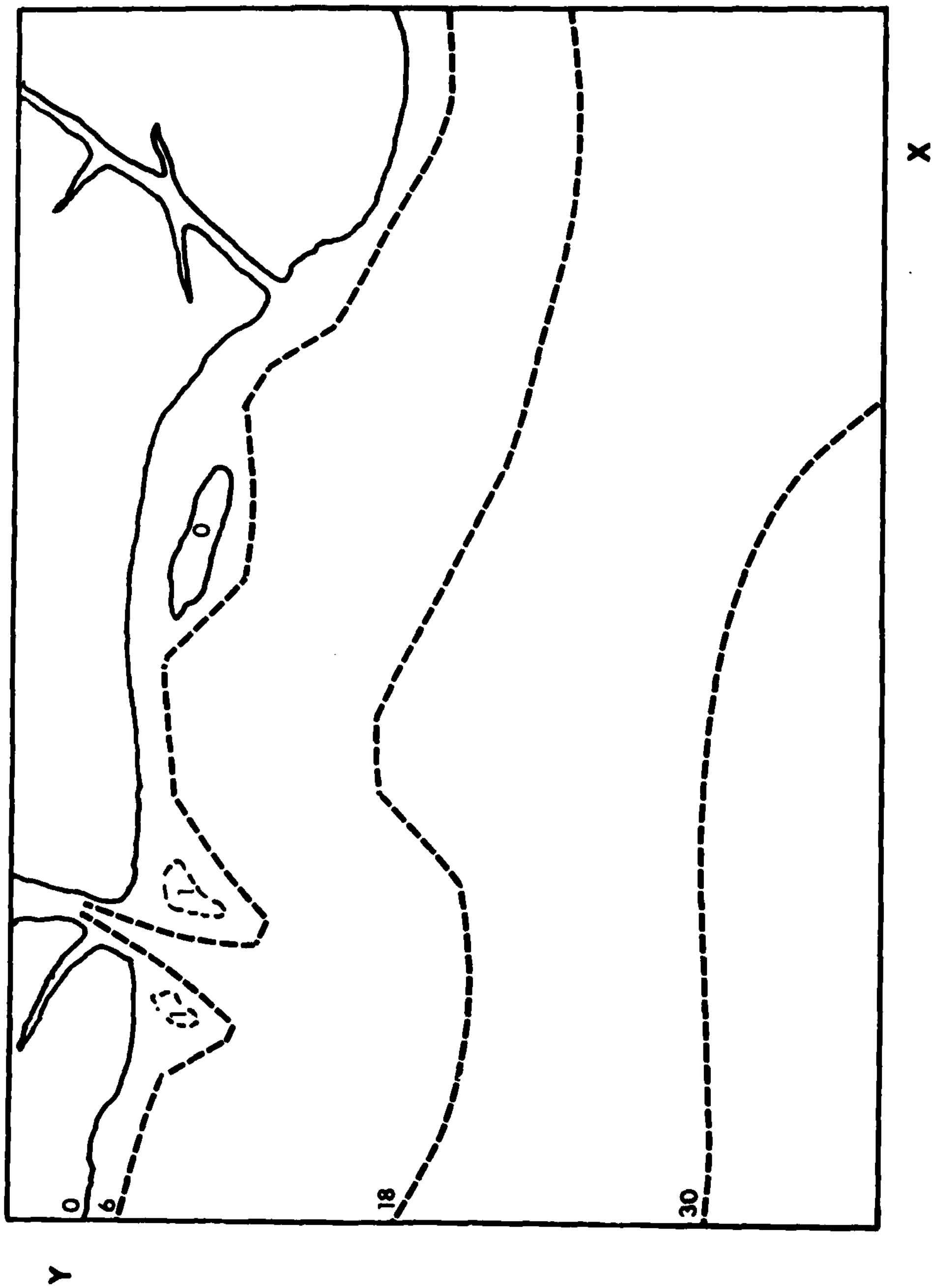
X-axis = 8 inches
Y-axis = 5.5 inches

If SCX = .1

MI = 81

MJ = 56

MI x MJ = 4536 (Total no. of grid points).



X
Y
0
6
18
30

tion on a hypothetical hydrographic chart.

Before drawing a perimeter, two questions need to be considered. First, what are the directions of wave approach? If the waves will be starting from the perimeter sides, extra distance along the X-axis will be needed to give the rays time to refract into the area of interest. Second, how many grid points will be generated? The number of grid lines crossing the X and Y axis (MI and MJ respectively) are given by

$$\begin{matrix}\text{MI}\\ \text{and}\\ \text{MJ}\end{matrix} = \frac{\text{Length of respective axis in inches}}{\text{Spacing interval between grid lines (SCX) also in inches}} + 1.$$

As interpreted from the above equation, the origin of the grid is (1,1). The value of SCX is user determined and will depend on the complexity of the bathymetry. The number of grid points generated is the result of multiplying MI and MJ together and must be less than the maximum of 20,000. The values of MI, MJ, and SCX will be entered into the program as card input.

STEP 2 - What to digitize. First the perimeter and the points where the contours cross the perimeter are digitized. Next, the contours are digitized. A problem arises in digitizing the shoreline. In Figure 3, for example, if the island is super-tidal, then primary breakers will be oceanward of the barrier. The application of the linear wave theory stops at the line of primary breakers. So for refraction purposes, the barrier acts as the shoreline. Figure 5 shows the resulting digitization of the shoreline. Notice the inlet to the right of the barrier was truncated.

The orientation of the shoreline with respect to a breaking wave is critical in calculations dependent on breaker height and breaker an-

gle. Two such calculations used in the program are the longshore energy flux factor and longshore sediment transport rate. To maintain the proper shoreline orientation, a constant slope is assumed from the first oceanward depth contour onto the beach. This is accomplished by digitizing a mirror image of the first contour onto the landward side of the shoreline (see Figure 5, the -6 foot contour). A second mirror image of the shoreline may be digitized landward of the first mirror image if changes in tidal elevations are to be considered. It is suggested these lines be drawn in before digitizing.

STEP 3 - Digitization preparation. Instructions on setting up the digitizer have been previously written by Jim Crabtree (personal communication) and only slightly modified in the following explanation.

The digitizer is turned on by a switch located near the upper center of the back panel. Before using the digitizer, the following switches on the Operator's Display Panel should be checked:

1. The IRG switch should be in the on position.
2. The switch labeled DIST POINT TIME MODE should be in the DIST mode.
3. The switch labeled $\Delta X - \Delta X + \Delta Y$ should be in the $\Delta X + \Delta Y$ position.
4. The magnetic tape unit on-off switch should be turned off.
5. The DISTANCE thumbwheels should be set to .050 - that is, a coordinate will be recorded every 5 hundredths of an inch.

To mount a magnetic tape reel on the tape unit, the following procedure should be followed:

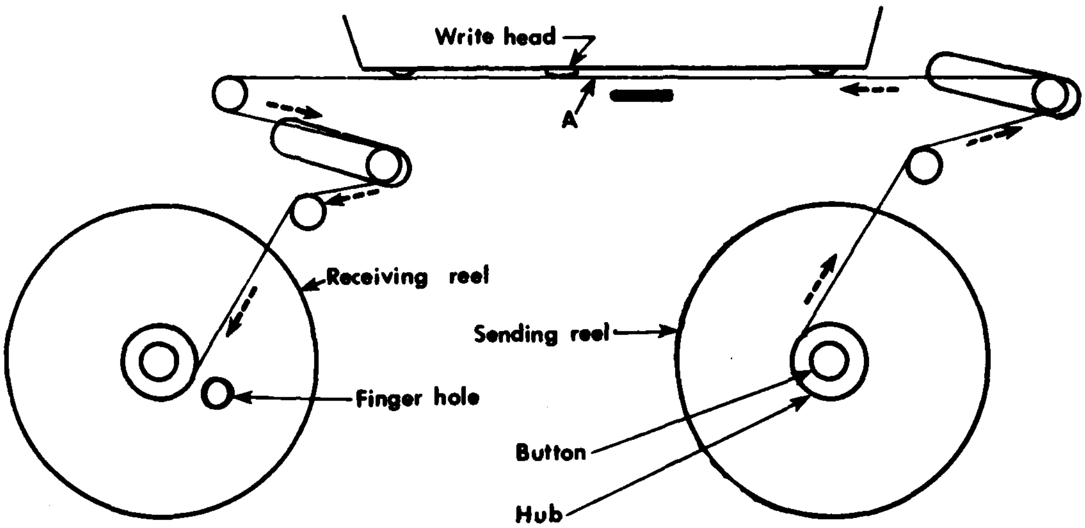
1. The magnetic tape unit must be turned off during the loading of a tape reel. If the unit is on during the loading process, it is possible to blow a fuse.
2. Open the front plastic cover to the tape unit.

3. Mount the tape reel on the right-hand hub by depressing the button in the center of the hub and sliding the tape reel completely onto the hub before releasing.
4. Then, using one hand to rotate the tape reel, follow the arrows indicated in Figure 4 to thread the tape to the receiving reel. Make sure that the tape passes between the metal plate and the write head at point A in Figure 4.
5. Wrap the tape around the receiving reel twice and make sure that all slack is taken up. The easiest way to wrap the tape around the receiving reel is to rotate the receiving reel with the left hand until the index finger can be inserted through the finger hole and press the tape against the center of the reel. Then rotate both reels clockwise with the right hand giving slack and the left hand taking it up.
6. Close the front plastic cover and turn the tape unit on.
7. Press the LOAD button once and release.
8. Press the LOAD button again and hold until the READY light comes on.
9. Press the FILE GAP button and release.
10. Press the FILE GAP button again and release.
11. Press the REWIND button and release.
12. Press the LOAD button and hold until the READY light comes on.

    The tape unit is now ready to record data.

Step 4 - Digitizing depth data. Tape the chart to the top of the digitizer table so that the x-axis increases to the right. Located on top of the table will be a cursor and keyboard. The crosshairs on the window of the cursor are used for guiding the cursor as the data is traced. As the cursor is moved, X and Y coordinates are recorded onto

Figure 4. Magnetic tape unit.


Write head
A
Receiving reel
Finger hole
Sending reel
Button
Hub

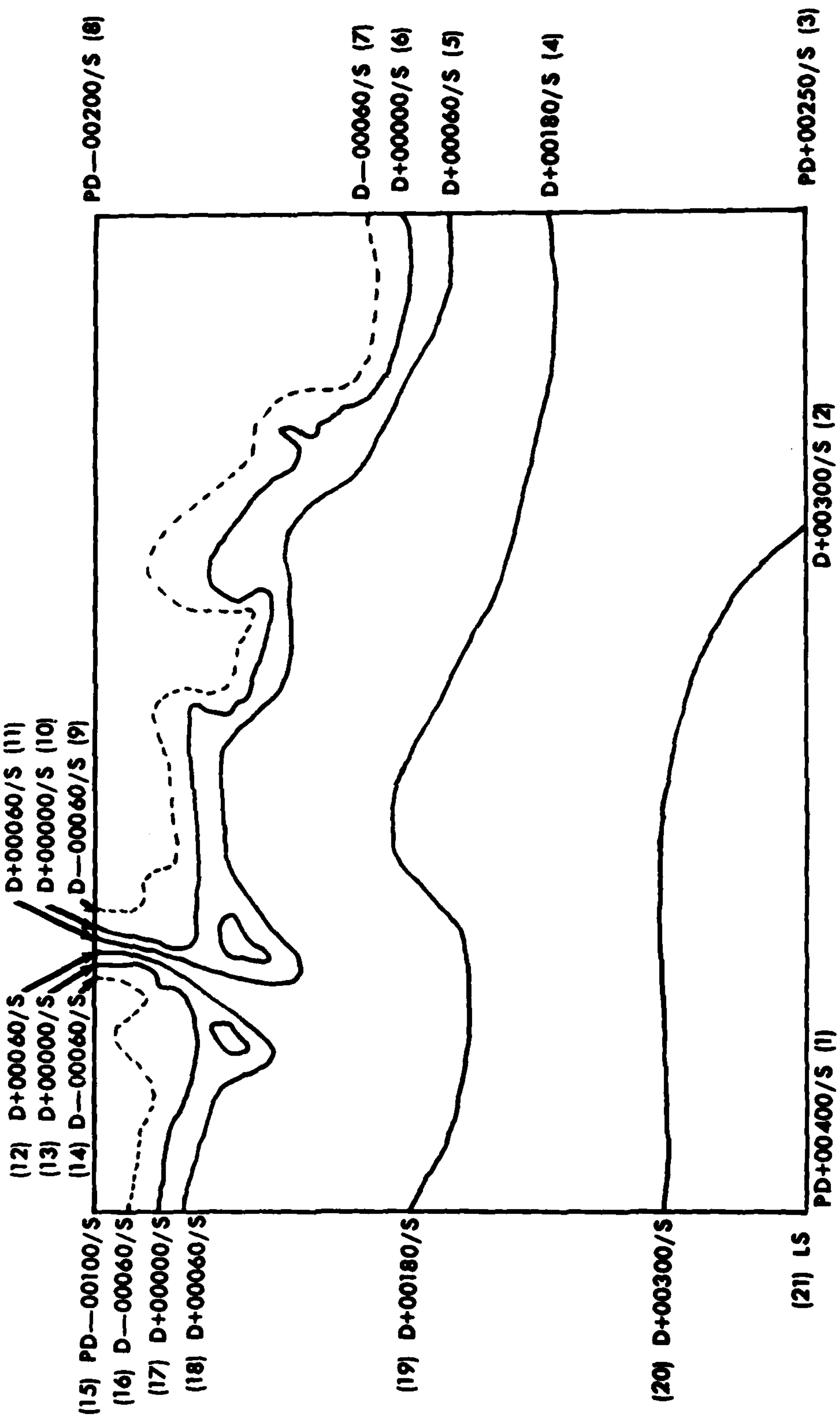
magnetic tape every .05 inch. The depth corresponding to the contour being digitized is entered on the keyboard.

The cursor is initially set at the lower left corner of the perimeter. Pressing the red button on the cursor resets the digitizer's X and Y coordinates to zero. Hold the cursor steady and press the blue (DATA) button. This places the digitizer into the data-recording mode. When the digitizer is in this mode, the red-orange DATA light on the Operator's Display Panel is on, and data can be recorded from the cursor or the keyboard. Next, press the yellow (HOLD) button on the cursor. The digitizer is now in the HOLD mode and locks in on the last digitized coordinate. Only data from the keyboard can be entered when the HOLD light on the Operator's Display Panel is on. The HOLD mode prevents the recording of extraneous data if the cursor is accidentally moved. The digitizer is now ready to record the first depth entry.

Depths are entered as a 5-digit number which the program converts to a number having one place to the right of the decimal. A depth entered as D+00525/s will be converted to 52.5 units below water level. Depths below water level are positive (+) and elevations above water level are negative (-). The few remaining codes will be discussed as they are used in the digitizing scheme presented below. The bracketed numbers correspond to the numbers in Figures 5, 6 and 7.

(1) This is the starting point on the chart. With the crosshairs of the cursor centered on the lower left corner, press the red button, then the blue and yellow buttons on the cursor. This point is recorded as the zero reference point. The digitizer is in the HOLD

Figure 5. Digitization of perimeter on hypothetical hydrographic chart.


PD—00200/S (8)
D—00060/S (7)
D+00000/S (6)
D+00060/S (5)
D+00180/S (4)
PD+00250/S (3)
D+00300/S (2)
PD+00400/S (1)
D+00060/S (11)
D+00000/S (10)
D—00060/S (9)
(12) D+00060/S
(13) D+00000/S
(14) D—00060/S
(15) PD—00100/S
(16) D—00060/S
(17) D+00000/S
(18) D+00060/S
(19) D+00180/S
(20) D+00300/S
(21) LS

mode which records keyboard data entry only. Corner depths are differentiated from depths on the perimeter by the notation 'PD'. All other depths begin with 'D'. Using Figure 5 as an example, enter PD+00400/s on the keyboard. In other words, the depth at this point is 40 feet. Press the yellow button to take the digitizer out of the HOLD mode. Cursor movement is now able to be recorded. With a steady motion, move the cursor to (2).

(2) Press the HOLD button to put the digitizer in the HOLD mode. Enter D+00300/s on the keyboard. Press the HOLD button to take the digitizer out of the HOLD mode and move the cursor to (3).

(3) Put the digitizer in the HOLD mode and enter PD+00250/s on the keyboard. Press the HOLD button to take the digitizer out of the HOLD mode and move the cursor to the first depth that crosses this section of the perimeter (4).

(4) Press the HOLD button. Enter D+00180/s on the keyboard. Press the HOLD button and move the cursor to the next point.

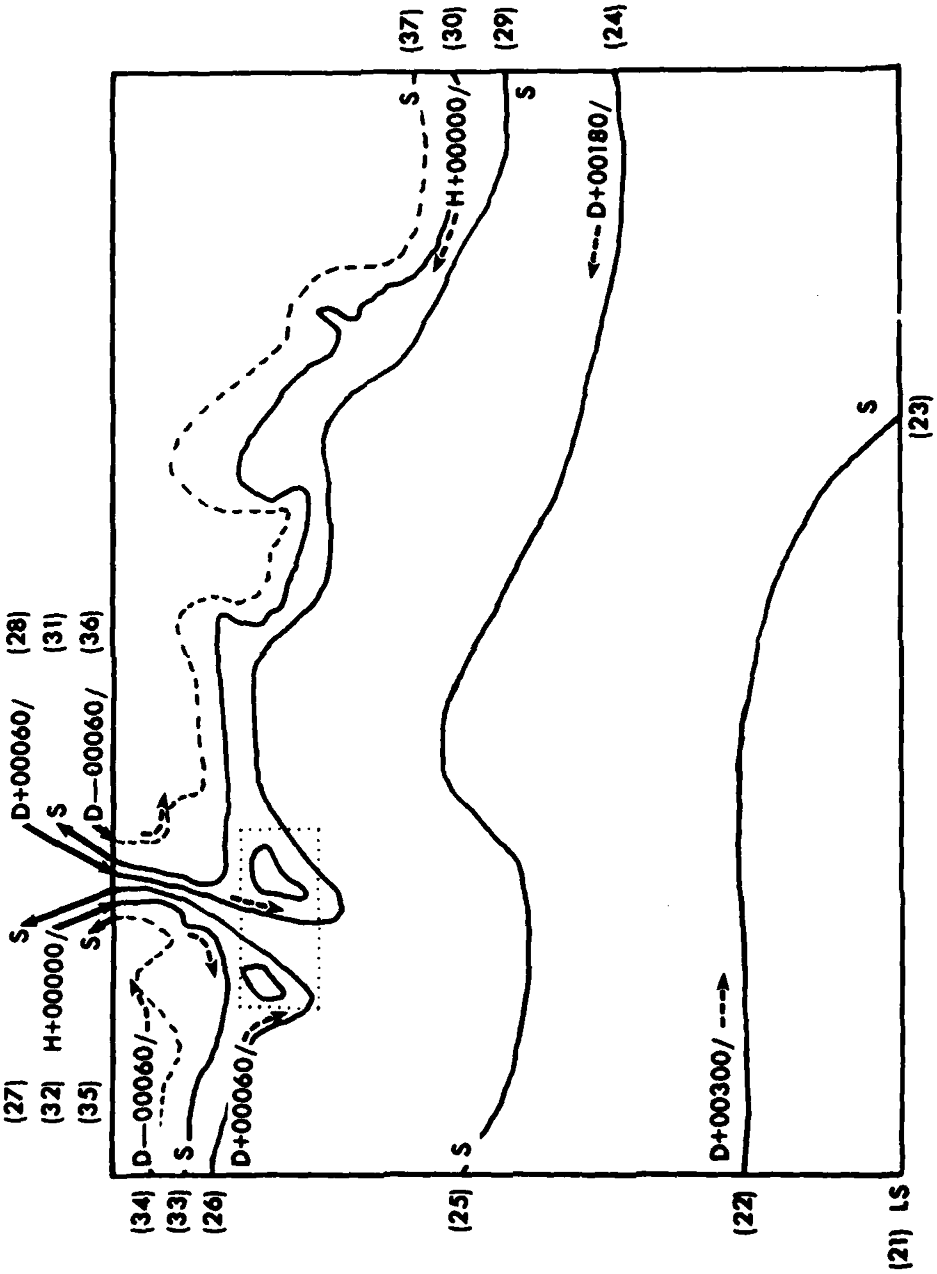
Continue digitizing the perimeter in the same fashion until point (21).

(21) The last point on the perimeter is the starting point. Press the HOLD button to enter the HOLD mode and enter 'LS' on the keyboard. This signifies the end of the perimeter. The contours are digitized next. Contour depths are denoted by a 'D' except for the shoreline which is symbolized by an 'H'. Refer to Figure 6 for the following discussion on digitizing the contours.

(21) Press the HOLD button to take the digitizer out of the HOLD mode. Steadily move the cursor to the first contour to be digitized, in this example (22).

Figure 6. Digitization of contours and shoreline on hypothetical hydrographic chart.

The shoals outlined by a dashed rectangle are enlarged in Figure 7.


(21) LS
(22)
(23)
(24)
(25)
(26)
(27)
(28)
(29)
(30)
(31)
(32)
(33)
(34)
(35)
(36)
(37)
D+00300/
D+00180/
H+00000/
D+00060/
D—00060/
H+00000/
D—00060/
D+00060/
D+00060/
S

(22) Press the HOLD button to put the digitizer in the HOLD mode. Enter D+00300/ on the keyboard. A contour is signified when an 'S' does not immediately follow '/'. Take the digitizer out of the HOLD mode and carefully trace the contour. Remember, contour traces will be plotted on the final output.

(23) Enter the HOLD mode and enter an S on the keyboard. This completes the trace of the 30 foot contour. Press the HOLD button to take the digitizer out of the HOLD mode and move the cursor to the next contour.

(24) Press HOLD. Enter D+00180/ on the keyboard. Trace the 18 foot contour.

(25) Press HOLD and enter the letter S on the keyboard. Press HOLD and move the cursor to the next contour.

The remaining contours are digitized in the same manner, except the shoreline. Replace D and an H for the shoreline and enter H+00000/ on the keyboard. As in the contour depths, the end of a segment of shoreline is denoted by an S. Refer to Figure 7 for the following bracketed numbers.

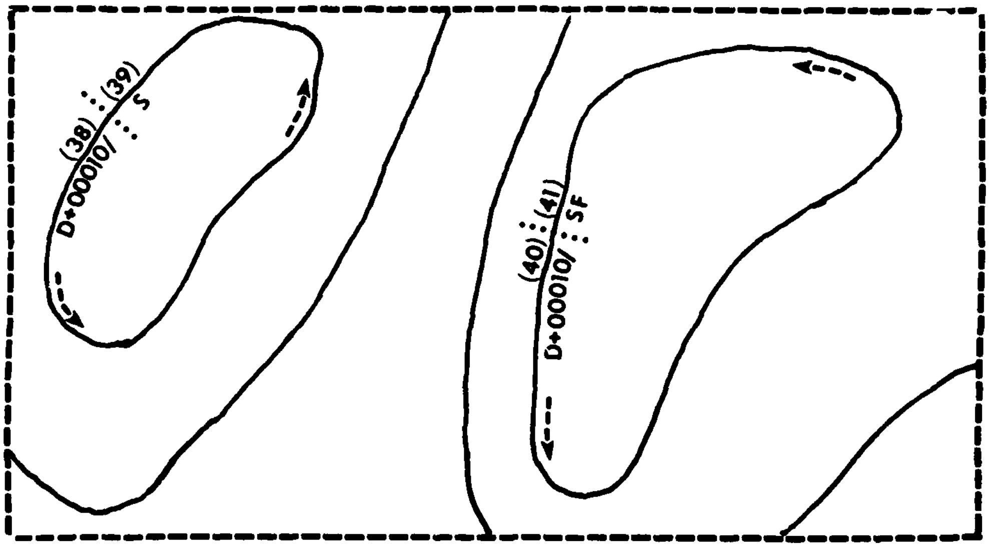
(37) After the S is entered on the keyboard signifying the end of the -6 foot trace, press the HOLD to take the digitizer out of the HOLD mode. Move the cursor to a point of one of the shoals (38).

(38) Press HOLD and enter the dpeth of the shoal, D+00010/ , on the keyboard. Press HOLD and with a steady motion, trace the shoal.

(39) Upon returning to the starting point, press HOLD and enter an S on the keyboard. Press HOLD again and move the cursor to the next shoal.

(40) Press HOLD. Enter D+00010/ on the keyboard. Press HOLD, taking the digitizer out of the HOLD mode and trace the contour.

Figure 7. Enlarged view of shoals digitized in Figure 6.


(38) ⋮ (39)
D+00010/ ⋮ S
(40) ⋮ (41)
D+00010/ ⋮ SF

(41) Again upon returning to the starting point, press HOLD and enter an S on the keyboard. This being the last contour to trace, enter an F on the keyboard (after the S) to signify the end of the digitized data.

(To Finish) The trace being complete, press HOLD to take the digitizer out of the HOLD mode and move the cursor in any direction until a beep is heard on the digitizer. This will create a complete record block of 4096 characters on the magnetic tape which is necessary for proper operation of the program. On the Operator Display Panel, press the FILE GAP button twice. This will indicate the end of this data file.

Step 5 - Dismounting the magnetic tape. The following steps are to be followed when unloading the magnetic tape unit:

1. Press the REWIND button and release.
2. After the magnetic tape has finished rewinding, turn the magnetic tape unit off.
3. Open the front plastic cover to the tape unit.
4. Use the left hand to rotate the left-hand reel counterclockwise to give tape slack. At the same time, use the right hand to rotate the right-hand reel counterclockwise to take up the slack tape. Continue this process until the tape has been wound onto the right-hand reel.
5. Remove the tape reel from the right-hand hub by depressing the button in the center of the hub and sliding the reel off before releasing.
6. If no more tapes are to be mounted, make sure the front plastic cover is closed. This will help to keep dust off of the write-

head assembly.

Step 6 - Final Step. Only one bathymetric map can be digitized per magnetic tape. To avoid the problem of running out of tapes, a small program written by J. Crabtree will copy the digitized data off the magnetic tape and store it onto disk, thereby freeing the tape for later use.

The tape first has to be brought to the user's service window in Computer Services Division (CSD). At the time of this writing CSD is located at the corner of Wheat and Main Streets. Remember to copy the number of the tape as this information is needed by the program. A program listing and information on how to implement this program is provided in PROGRAMS: TTD (Tape to Disk).

PROGRAMMING CONSIDERATIONS

Determination of Input Parameters

MI, MJ, SCX and GRID. Refer to the Digitized Depth Input (Step 1) for the calculation of MI, MJ, and SCX. GRID is the dimension of the side of a grid square expressed in map feet and is a function of SCX and the scale of the map. GRID is given by

$$\text{GRID (feet)} = (\text{SCX} \times \text{map scale}) / 12$$

For example if Figure 3 had a 1:80,000 scale, GRID would equal 666.67 feet (.1 x 80000/12), if SCX = .1.

XSG, YSG, SCNV, DGXL and DGYL - Window parameters. A window is an area inside the present grid being processed. This window enables the user to study a particular area in the grid in greater detail by using a larger scale grid. REFRAC will trace the rays through the window and generate the necessary input parameters to be used in a refraction run on the larger scale grid. To create the window on the small scale grid, the X (XSG) and Y (YSG) coordinates of the lower left corner of the window position, the ratio of the two scales (SCNV) and the length of the axes of the window (DGXL and DGYL) expressed in inches of the small scale grid are input in the preliminary run. XSG and YSG are given by

$$\begin{array}{c}\text{XSG}\\ \text{or}\\ \text{YSG}\end{array} = \frac{\text{distance (inches) from respective X or Y axis of the small scale grid to the lower left corner of the window}}{\text{SCX}} + 1$$

SCNV may be calculated by

$$\text{SCNV} = \text{small map scale/larger map scale}$$

SCNV is considered a magnification factor and will always be greater than 1.

The following equation yields DGXL and DGYL:

DGXL or DGYL = respective axes length (inches) / SCNV
(inches)   of larger scale map

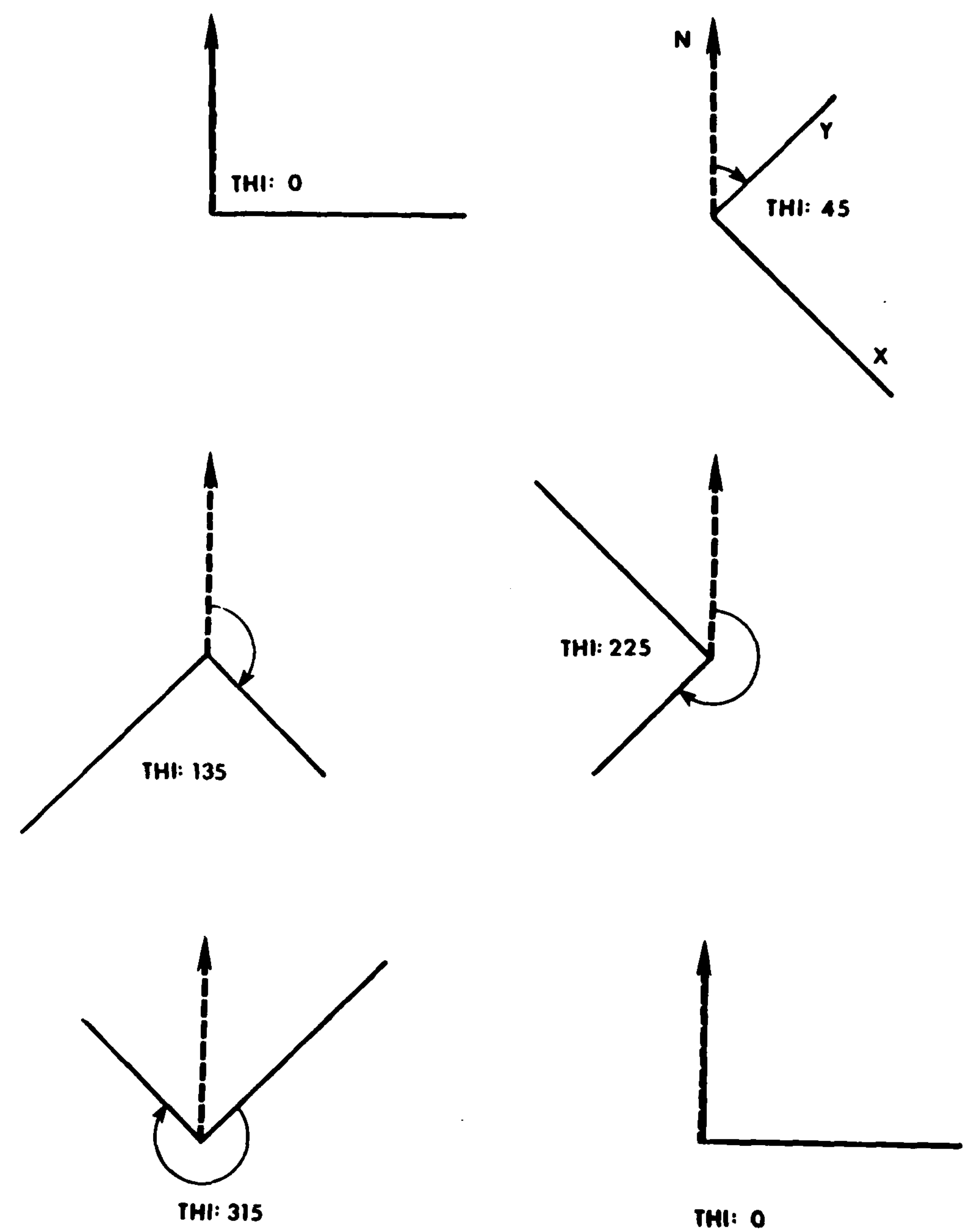
This initial run on the small scale grid will generate the starting coordinates (X and Y), the refraction coefficients of that time step (RK) and of the previous time step (RK1) and the azimuth (AZIMTH) for a ray to be used as input in a subsequent run on the larger scale grid. These wave characteristics, generated for every ray that crosses the window boundary, can be either printed onto paper, punched onto cards or stored on disk. The program is presently set up to store these values on disk under a user determined data set name, so they can be easily accessed. See JCL considerations under REFRAC in the section on PROGRAMS for further information. If RK, RK1, and AZIMTH are not the results of a previous run, they will have to be hand calculated for each ray and keypunched onto cards for input into the program. (This only applies to rays starting in shallow water.)

NORAYS. A maximum of 400 rays can be refracted per set. If the number of rays is not known, such as in the case of window-generated input, set NORAYS equal to 400.

SK and SK1. SK is the shoaling coefficient at water depth for the present time step. If a set of rays start in shallow water (SK is greater than 1), set SK to 1 on input because the program will calculate the proper value. SK1 is the shoaling coefficient at water depth for starting location of a ray. Most refraction diagrams are of swell conditions; therefore, SK1 usually equals 1.

THI and STAZ. THI is the clockwise angle between north on the map and the positive y-axis of the grid. See Figure 8. STAZ is the azimuth or the clockwise angle between north on the map and the deep-

Figure 8. THI is the clockwise angle between north on the map and the positive y-axis of the grid.


THI: 0
N
Y
THI: 45
X
THI: 135
THI: 225
THI: 315
THI: 0

water direction of wave approach. See Figure 9.

GRINC, UNIT, WPI, GRID and KPLOT. UNIT is the time step for a set of rays. WPI is the number of wave periods between tick marks on a ray. The variable KPLOT is calculated in the program and determines the points on a ray where tick marks will be plotted. KPLOT is dependent on the values of UNIT, WPI and GRID. GRINC is the deepwater step length, expressed as a fraction of a grid square and is given by:

GRINC = UNIT x CO/GRID.

CO, the deepwater wave celerity, equals 5.12 times the period (T). In the above equation, UNIT is the only variable user determined and should be chosen so the resulting value of GRINC is approximately .5.

KPLOT is given by:

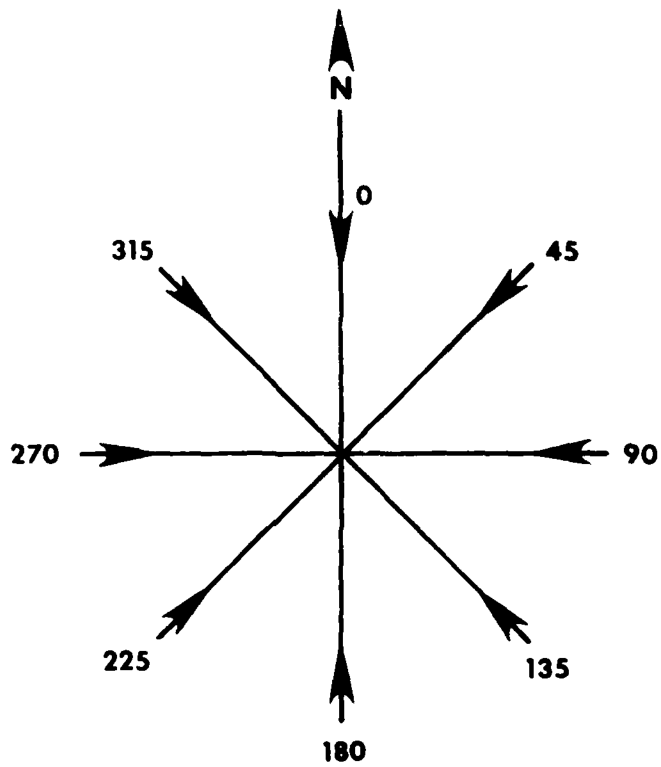
KPLOT = (T x WPI/UNIT) + .1

WPI should be chosen so the value of KPLOT is greater than or equal to 1. Optimal results are achieved if KPLOT is approximately 10.

Miscellaneous

Depending on the needs of the user, there is the choice of printing or not printing the depth grid values or wave information. Refer to JCL Considerations if either of these options is desired. The amount of printed output may be decreased by both of the variables NPRINT and PD. NPRINT is the user determined printing interval for information along a ray. A suggested value for NPRINT is 10. PD is the depth at which printing will begin. The advantage of PD is that it enables the user to limit printing to where the rays are more strongly refracted - that is, in shallow depths. Over 10,000 lines of printout can easily be generated when refracting a set of more than 50 rays. Turnaround time (time it takes to get printed results) and CPU time (execution

Figure 9. Determination of deepwater azimuth for a ray expressed in degrees (STAZ). Wave approach depicted by direction of arrow.


N
0
45
90
135
180
225
270
315

time) are decreased when the number of lines printed is kept to a minimum.

Keypunching and computation time can be saved by the two input variables IWR and YFA. The card input falls into two categories, the information needed for a set of rays and the information on individual rays such as starting coordinates. If more than one set of rays is being processed and the individual wave characteristics will be the same, set IWR equal to 1 for the sets after the first set. The program will store the first set of ray characteristics and use the same information for the subsequent sets until all the sets of rays are processed or until IWR equals zero. If IWR equals zero, the individual wave characteristics have to be read off cards or disk. YFA adds a constant to the y-coordinates of the starting locations for a set of rays. This enables the same wave characteristics cards to be used for a variety of periods by moving the starting positions of rays relative to the shoreline.

The user has a choice between two plotting devices, the Gould electrostatic plotter or the Calcomp drum plotter. The Gould plotter is faster - minutes compared to hours - but the Calcomp plotter has better resolution. The increased resolution may be desired if the refraction diagrams are to be photographed.

The Gould plotter has a maximum length (x-axis) of 327 inches and height (y-axis) of 63 inches. The width of the plotter is only 10.5 inches; therefore, any width greater than 10.5 inches (but less than 63) will cause the plot to be 'stripped'. The input variables FAC or BOUND can reduce the plot size to avoid stripping. Because of the fast plotting time, the Gould plotter is excellent for debugging or obtaining work copies of the refraction diagram.

The maximum length of the x-axis for the Calcomp plotter is limited

to the length of paper on the roll. The maximum length of the y-axis is 29.5 inches. For purposes of photocopying the diagram, liquid ink can be requested instead of the standard black ballpoint pen.

JCL Considerations

The JCL (Job Control Language) presented in this section is coded for an IBM 370/168 System. Job control cards begin with a // (slash-slash). REFRAC is compiled, loaded and then stored on disk (mass storage) in a program library called WORK.

The following discussion explains how to implement REFRAC and the various options available by small changes in the JCL. (Refer to JCL listing.) The first 3 cards are the JOB card. Included on the JOB card are the account number (N3100138), maximum number of lines to be printed (50,000) and maximum number of plot records (99990). TIME has the format (minutes, seconds); therefore, the time requested in the above JCL listing is 2 minutes and 30 seconds. The time can be decreased depending on the number and size of diagrams to be plotted. USER and PASSWORD information is obtained when an account number and disk space are requested from Computer Services Division.

The remainder of the JCL between the fourth card, PROC, and the last card, PEND, is called an in-stream procedure. This procedure accesses the necessary libraries and data sets whenever it is called. A call to the procedure is made by an EXEC statement following the PEND statement. More detail is given in the several examples following the listing of the in-stream procedure.

The REFRAC procedure is set up to plot the results on the Gould plotter at the Social and Behavior Sciences Lab located in Gambrell Hall (University of South Carolina). The Calcomp drum plotter is located in Computer Services Division (CSD) and the results can be plotted there with the following minor changes to the JCL. Change:

JCL LISTING OF THE IN-STREAM PROCEDURE REFRAC

```
//N3100138 JOB (N3100138,50,9999),'WAVE REFRACTION',MSGLEVEL=(1,1),
//  USER=N310013,PASSWORD=CRD,REGION=600K,
//  TIME=(2,30)
//REFRAC PROC DEPGRID='DUMMY,',WAVDATA=NULLFILE,NEWWAV=NULLFILE
//STP1 EXEC PGM=REFRAC
//STEPLIB DD DSN=N310013.WORK,DISP=SHR
//    DD DSN=SM1.LINKLIB,DISP=SHR
//SYSPRINT  DD  SYSOUT=A
//SYSOUT  DD  SYSOUT=A
//SORTLIB  DD  DSN=SM1.SORTLIB,DISP=SHR
//SORTWK01  DD  UNIT=SYSDA,SPACE=(TRK,200,,CONTIG)
//SORTWK02  DD  UNIT=SYSDA,SPACE=(TRK,200,,CONTIG)
//SORTWK03  DD  UNIT=SYSDA,SPACE=(TRK,200,,CONTIG)
//FT06F001 DD SYSOUT=A
//FT07F001 DD DSN=&NEWWAV,UNIT=3330V,MSVGP=USCP,
//    DISP=(NEW,CATLG,DELETE),SPACE=(TRK,(5,5),RLSE),
//    DCB=(LRECL=50,BLKSIZE=2000,RECFM=FB)
//FT08F001 DD &DEPGRID.SYSOUT=A
//FT11F001 DD DSN=N3100138.D04,DISP=(NEW,DELETE,DELETE),
//           UNIT=SYSDA,SPACE=(CYL,10),
//           DCB=(BLKSIZE=12000,LRECL=16,BUFNO=1,RECFM=FB)
//FT12F001  DD  DSN=N3100318.D01,DISP=(NEW,DELETE,DELETE),
//               UNIT=SYSDA,SPACE=(CYL,10),
//               DCB=(BLKSIZE=12000,LRECL=12,BUFNO=1,RECFM=FB)
//SORTIN  DD  DSN=*.FT12F001,DISP=(OLD,DELETE,DELETE),
//               UNIT=SYSDA,VOL=REF=*.FT12F001,
//               DCB=(BLKSIZE=12000,LRECL=12,BUFNO=1,RECFM=FB)
//SORTOUT  DD  DSN=N3100138.D02,DISP=(NEW,DELETE,DELETE),
//               UNIT=SYSDA,SPACE=(CYL,10),
//               DCB=(BLKSIZE=12000,LRECL=12,BUFNO=1,RECFM=FB)
//FT13F001  DD  DSN=*.SORTOUT,DISP=(OLD,DELETE,DELETE),
//               UNIT=SYSDA,VOL=REF=*.SORTOUT,
//               DCB=(BLKSIZE=12000,LRECL=12,BUFNO=1,RECFM=FB)
//FT10F001  DD  DSN=N3100138.D03,DISP=(NEW,DELETE,DELETE),
//               UNIT=SYSDA,SPACE=(CYL,2),
//               DCB=(BLKSIZE=12000,LRECL=12,BUFNO=1,RECFM=FB)
//FT17F001 DD DSN=&DEPDATA,DISP=SHR,LABEL=(,,,IN)
//FT25F001 DD DSN=&WAVDATA,DISP=SHR,LABEL=(,,,IN)
//FT05F001 DD DDNAME=SYSIN
//SYSVECTR DD DSN=&&VECTORS,UNIT=SYSDA,DISP=(NEW,PASS),
// SPACE=(1320,(500,200)),DCB=BLKSIZE=1320
//SYSPOUT DD SYSOUT=A
//STP2 EXEC PGM=BTSTN50
//STP2.SYSUDUMP DD SYSOUT=A
//STEPLIB DD DSN=ACAD.SUBLIB.G5005,DISP=SHR
//SYSVECTR DD DSN=&&VECTORS,DISP=(OLD,DELETE)
```

```
//SYSUT1 DD DSN=&&SYSUT1,UNIT=SYSDA,SPACE=(18200,200)
//SYSPLOT DD SYSOUT=(B,,PLOT),DEST=RMT8
//SYSPOUT DD SYSOUT=A
//   PEND

         .
         .    CALLS TO ABOVE PROC
         .
```

1. card #5 (EXEC card) to

```
//STP1  EXEC  PGM=CALCOMP
```

2. replace the 10 cards between (excluding)

```
//FT05001  DD  DDNAME=SYSIN
          and
//  PEND
   with one card
// GO.PLOTTAPE  DD  DSN=DRUM.PLOT,UNIT=TAPED,
           DISP=(NEW,KEEP),DCB=DEN=2
```

If the Calcomp plotter is used, a DP number is returned on the front page of the printout. This number is the location of the plot on tape and needs to be called into CSD in order to obtain the plotted results.

Three types of data sets are of primary concern to the user. The first type is the digitized depth data, DEPDATA, which resides on disk having been previously copied from magnetic tape by the program TTD. (User must have previously requested disk space from CSD.) The second type, NEWWAV, is created during a run in which window boundaries had been specified. The output wave data, NEWWAV (X, Y, AZIMTH, RK, RK1), is stored on disk to be read in a subsequent run. As input data NEWWAV is called WAVDATA, which is the third type of data set.

Data set names (DSN) may consist of up to 44 alphanumeric characters (including periods used for separation). A period must separate each 8 characters or less and must be followed by an alphabetic character. The first 7 characters of the DSN are the first 7 characters of the 8 character account number. Data set names must be unique or an error will occur upon the creating the data set. A data set name such as N310013.PRICE.INLET could be used for the account number N3100138 and represent a data set (of any of the three types) for Price Inlet, South Carolina.

The general JCL format for the program is:

```
//Job Card(s)
//REFRAC PROC . . . .
        .
        .  in-stream procedure
        .
//PEND
/*
//stepname EXEC REFRAC, data set type='data set name',
                  data set type='data set name'
//SYSIN DD
        .
        . card input as described in PROGRAM DESCRIPTION
//stepname EXEC REFRAC, data set type='data set name'
//SYSIN DD
        .
        . card input
        .
//
```

As mentioned earlier, a call to the in-stream procedure (REFRAC) sets up the program libraries and data sets necessary for the refraction program. A call to the procedure is made when an EXEC REFRAC card is encountered in the JCL. A job may consist of more than one call by simply adding another EXEC REFRAC card and its corresponding data cards to the last data input card from the previous call. The above example is termed a multistep job because it calls the in-stream procedure twice. The program is terminated by a // in columns 1 and 2 of the last card.

The stepname is from 1 to 8 alphanumeric characters, the first of which must be alphabetic. The purpose of the EXEC REFRAC card is to specify the data sets that are to be read or created during the execution of the refraction program. Examples of data set types are explained below. The various options are also shown.

1. A simple refraction program reads the depth data off disk, doesn't specify a window and reads all wave parameters off cards. In other words, of the 3 data types, only DEPDATA needs to be specified.

```
//STP EXEC REFRAC,DEPDATA='N310013.SOUTH.CAROLINA'
```

2. The above example results in a refraction diagram of the South

Carolina coast. In the present example, a window is specified in the card input; therefore, a data set name will have to be given for NEWWAV to store the wave information generated. If the window is of Price Inlet, then

```
//STP EXEC REFRAC,DEPDATA='N310013.SOUTH.CAROLINA',
// NEWWAV='N310013.PRICE.INLET.WAVE'
```

This data set may now be read in a subsequent refraction analysis on a larger scale chart of Price Inlet.

3. Using the above-created data set and the digitized depth data for Price Inlet, a more detailed analysis can be obtained.

```
//STP EXEC REFRAC,DEPDATA='N310013.PRICE.INLET',
//        WAVDATA='N310013.PRICE.INLET.WAVE'
```

Note: In this example, the card input variables IWR and IRED EQUAL 0 and 25 respectively (see PROGRAM DESCRIPTION (Card Input)).

4. The printing of the depth grid is suppressed unless explicitly requested. This is accomplished by punching DEPGRID= in the data set type location.

```
//STP EXEC REFRAC,DEPDATA='N310013.DEPTH.DATA',
//           DEPGRID =
```

If NEWWAV is also specified then

```
//           DEPGRID=,NEWWAV='N310013.WAVE'
```

5. The printing of the title page and all wave information may be suppressed if only the plot is desired. Refer to card input listing for proper positioning of cards described in examples 5 and 6. Add the following JCL card after the 'EXEC REFRAC' card and before the 'SYSIN DD *' card

```
//STP1.FT06F001 DD DUMMY
```

6. The wave parameters generated for a window may be punched on

cards instead of stored on disk by adding the following JCL card between the 'EXEC REFRAC' card(s) and 'SYSIN DD *' card

```
//STP1.FT07F001 DD SYSOUT=B
```

Program Listing, Card Input and Example of Output

The following listing is a deck setup including both JCL and card input. A refraction analysis of South Carolina coast results from the first call to the in-stream procedure. The wave information generated at the window boundaries is used in the second call of the procedure, thereby producing a detailed analysis of the window area. Refer specifically to examples 2, 3, and 5 for further explanations.

A sample of the output includes the title page, information on one ray and the refraction diagram. The information is from the window area analyzed above. Following the sample output is a complete listing of the program REFRAC and the necessary JCL to compile, load and store it on disk (if it has not already been stored).

PROGRAMS

COASTAL RESEARCH CENTER TECHNICAL REPORTS
(Geology Department, Univ. of Massachusetts)

1. Offset coastal inlets.
   M. O. Hayes, V. Goldsmith, and C. H. Hobbs; Tech. Rept. No. 1-CRC, 1972.

2. Forms of sediment accumulation in the beach zone.
   M. O. Hayes; Tech. Rept. No. 2-CRC, 1972

3. Hydraulic equivalent sediment analyzer (HESA).
   F.S. Anan; Tech. Rept. No. 3-CRC, 1972

4. Glacial environment and processes in southeastern Alaska.
   J.H. Hartshorn and G.M. Ashley; Tech. Rept. No. 4-CRC, 1972.

5. Sedimentation and physical limnology in proglacial Malaspina Lake, Alaska.
   T.C. Gustavson; Tech. Rept. No. 5-CRC, 1972.

COASTAL RESEARCH DIVISION TECHNICAL REPORTS
(Dept. of Geology, Univ. of South Carolina)

6. Coarse-grained sedimentation on a braided outwash fan, northeast Gulf of Alaska.
   J.C. Boothroyd; Tech. Rept. No. 6-CRD, 1972.

7. Bank margin morphology and sedimentation, Lucaya, Grand Bahama Island.
   D.K. Hubbard, L.G. Ward, D. M. FitzGerald, and A. C. Hine; Tech. Rept. No. 7-CRD, 1976.

8. Selected environmental criteria for the design of artificial structures on the southeast shore of Lake Erie.
   R.H. Clemens; Tech. Rept. No. 8-CRD, 1976.

9. Coastal dynamics and sediment transportation, northeast Gulf of Alaska.
   D. Nummedal and M.F. Stephen; Technical Rept. No. 9-CRD, 1976.

10. Morphologic and hydrodynamic characteristics of terrestrial fan environments.
    D. Nummedal and J.C. Boothroyd; Tech. Rept. No. 10-CRD, 1976.

11. Terrigenous clastic depositional environments.
    M. O. Hayes and T. W. Kana, eds.,; Tech. Rept. No. 11-CRD, 1976.

12. Coastal morphology and sedimentation - Lower Cook Inlet, Alaska.
    M. O. Hayes, P. J. Brown, and J. Michel; Tech. Rept. No. 12-CRD, 1976.

13. The Carolina Bays: A comparison with modern oriented lakes.
    R. T. Kaczorowski; Tech. Rept. No. 13-CRD, 1977.

14. Variations in tidal inlet processes and morphology in the Georgia Embayment.
    D.K. Hubbard; Tech. Rept. No. 14-CRD, 1977.

15. Coastal morphology, sedimentation and oil spill vulnerability - Northern Gulf of Alaska.
    C. H. Ruby, Tech. Rept. No. 15-CRD, 1977.

16. Two years after the *Metula* oil spill, Strait of Magellan, Chile: oil interaction with coastal environments.
    Anne E. Blount, Tech. Rept. No. 16-CRD, 1978.

17. Influence of wave refraction on coastal geomorphology - Bull Island to Isle of Palms, South Carolina.
    C. Fico, Tech. Rept. No. 17-CRD, 1978.

```
FORMATTING OF CALLS TO PROCEDURE REFRAC (JCL) & SAMPLE
OF CARD INPUT

FIRST CALL -- REFRACTS A SET OF WAVES (READ FROM CARDS)
ON THE S.C. SHELF, THROUGH THE WINDOW AREA OF CAPE
ROMAIN TO FOLLY ISLAND. THEREFORE, WAVE INFORMATION IS
GENEPATED & STORFD ON DISK TO BE USED IN A
SUBSEQUENT RUN.

SECOND CALL -- READS THE ABOVE CREATED DATA SET FROM
DISK & REFRACTS THE CONTINUED WAVES ACROSS THE MORF
DETAILED GRID OF CAPF ROMAIN TO FOLLY ISLAND.

THF SAMPLE OUTPUT FOLLOWING THIS LISTING INCLUDES THE
TITLE PAGE & WAVE INFORMATION ON RAY #1 FROM THE SFCOND
CALL TO REFRAC. ALSO INCLUDED IS THE RESULTING WAVE
REFRACTION DIAGRAM.


//  USER=N310013,PASSWORD=CRD,REGION=600K,
//  TIME=(2,30)
//N3100138 JOB (N3100138,50,9999),'WAVE REFRACTION',MSGLEVEL=(1,1),
//REFRAC PROC DEPGRID='DUMMY,',WAVDATA=NULLFILE,NEWWAV=NULLFILE
          .
          .    IN-STREAM PROC
          .
//   PEND
//SC EXEC REFRAC,DEPDATA='T310010.SOUTH.CAROLINA',
//  NEWWAV='T310010.SC.SC1973.T10A135'
//STP1.FT06F001 DD DUMMY
//SYSIN DD *
SOUTH CAROLINA  WINDOW--SC1973
   .5
1975  FATHOMS         MLW
```

```
181    91 4000    10 7353.1666        6.        .002
                  .2      67.44    60.88     5.515      6.890     3.626

  1
 10   399         10.         1.        1.        1.      318.      135.      20.
                  20.                                   80.
  0
     78.0         8.
     78.1         8.
     78.2         8.
      .
      .
      .
     93.8         8.
     93.9         8.
     94.0         8.
//SCTF EXEC REFRAC,DEPDATA='T310010.ROMAINE.FOLLY',
//  WAVDATA='T310010.SC.SC1973.T10A135'
//SYSIN DD *
SC-1973
  .47
1973  FEET            MLW
 191  101 4000    10  1333.333        1.        .002
                  .2       191.
  1
 10   170         10.         1.        1.        1.      318.      135.      12.
        1         12.
 25
//
```

```
WAVE REFRACTION PROGRAM--COASTAL RESEARCH DIVISION

WAVE REFRACTION ANALYSIS      SC-1973
                                05/04/78

INPUT PARAMETERS :

MI= 191             MJ= 101          LIMNPT= 4000     NPRINT=  10     GRID= 1333.3328   DCON=    1.0000
DELTAS=0.002

BOUND=  0.0         SCX=   0.20000   XSG=191.00       YSG=  0.0       SCNV= 0.0         DGXL= 0.0
DGYL= 0.0           SCALE=  6666.664 NOSETS=  1

LPLOT=    10        NORAYS=  170     T=10.00          HO= 1.00        SK= 1.00          SK1= 1.00
THI= 318.00         STAZ= 135.00     UNIT=   12.00
ISP=  0             LCK=  1          WPI=  12.00      CKDEP=  0.0     DF= 0.0           IWR=  0
PD=   60.00         YFA=  0.0

MAP DATE: 1973        DEPTH IN FEET
```

05/04/78

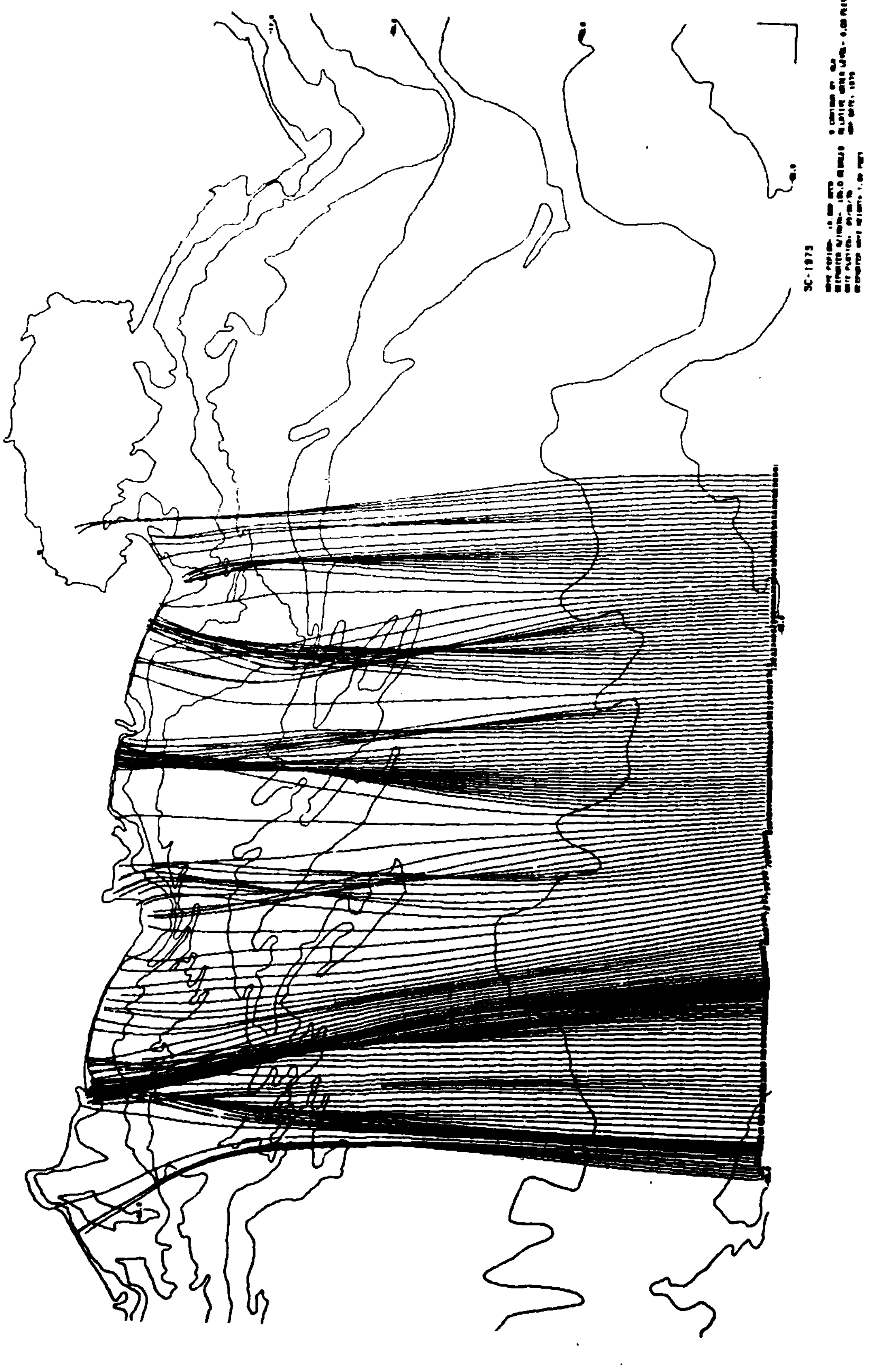
SET NO. 1. RAY NO. 1. PERIOD= 10.000 SECS.
GRINC = 0.460837. TIME STEP = 12.000 SECS.. WAVE FRONT INCREMENT = 120.00 SECS.

POINT	X	Y	AZIMUTH	DEPTH	LENGTH	SPEED	RK	SK	HEIGHT	UMID	UBOT	TOTAL ENERGY	GROUP VELOCITY	TOTAL POWER	LONGSHORE POWER	DIR
1	44.0	1.5	135.0		512.0	51.2			1.00							
10*	44.2	4.7	140.5	60.0	385.2	38.5	1.154	0.922	1.06	0.33	0.29	3487.84	30.13	272.83	135.30	R
20*	44.3	8.2	140.8	58.2	380.9	38.1	1.175	0.924	1.09	0.34	0.31	3591.50	30.01	282.98	107.59	R
30*	44.5	11.6	141.2	55.9	375.4	37.5	1.191	0.926	1.10	0.36	0.32	3656.92	29.85	290.75	106.33	R
40*	44.7	14.9	141.5	53.7	369.7	37.0	1.201	0.929	1.12	0.37	0.34	3683.36	29.66	295.48	109.30	R
50*	44.9	18.2	141.9	51.5	363.9	36.4	1.204	0.932	1.12	0.38	0.35	3666.28	29.46	296.73	110.95	R
60*	45.2	21.5	142.4	49.2	357.6	35.8	1.204	0.936	1.13	0.40	0.36	3634.12	29.21	296.89	102.93	R
70*	45.4	24.7	142.7	47.4	352.5	35.3	1.221	0.939	1.15	0.41	0.38	3708.55	29.01	305.15	68.34	R
80*	45.7	27.8	142.7	46.1	348.8	34.9	1.252	0.942	1.18	0.43	0.40	3882.12	28.85	321.08	15.02	R
90*	45.9	30.9	142.7	44.9	345.1	34.5	1.300	0.945	1.23	0.46	0.42	4163.25	28.68	346.07	52.02	L
100*	46.2	34.0	142.6	43.7	341.4	34.1	1.368	0.948	1.30	0.49	0.46	4589.57	28.52	383.35	116.97	L
110*	46.4	37.1	142.3	42.6	337.7	33.8	1.461	0.950	1.39	0.54	0.50	5211.84	28.34	437.41	190.11	L
120*	46.6	40.1	141.6	41.4	334.0	33.4	1.595	0.953	1.52	0.60	0.56	6179.68	28.16	521.06	258.42	L
130*	46.8	43.1	141.2	40.3	330.4	33.0	1.800	0.957	1.72	0.69	0.64	7832.37	27.98	663.39	325.71	L
140*	46.9	46.0	140.3	39.3	325.7	32.7	2.151	0.960	2.06	0.84	0.78	11134.95	27.79	947.28	433.68	L
150*	47.0	48.9	139.3	38.4	323.7	32.4	2.895	0.962	2.79	1.15	1.07	20110.78	27.64	1716.89	777.64	L
160*	47.1	51.8	138.2	37.3	320.0	32.0	6.099	0.966	5.89	2.47	2.31	88853.88	27.44	7618.98	3384.43	L
164	47.1	52.7	137.9	36.9	318.4	31.8	10.498	0.967	10.16	4.29	4.02	262760.31	27.35	22571.17	9901.87	L

RAY STOPPED, WAVE BREAKS AT X= 47.08 Y= 52.71

LONGSHORE ENERGY FLUX FACTOR: PLS= 0.9858570E 04 FT-LBS/SEC/FT OF BEACH FRONT
LONGSHORE TRANSPORT RATES:
FUNCTION OF PLS: Q= 0.6943926E 06 CUBIC YARDS/YR FACING OCEAN: TRANSPORT TO L
FUNCTION OF HB: Q= 0.2063037E 08 CUBIC YARDS/YR GALVIN(1972) - GROSS TRANSPORT RATE

METRIC CONVERSIONS:
PLS= 0.5610670E 11 ERGS/METER*SEC
Q= 0.7161657E 07 CUBIC METERS/YEAR


SC-1973

LISTING OF THE PROGRAM REFRAC AND THE NECESSARY JCL TO COMPILE, LINK AND STORE IT ON DISK

```
//SETUP JOB (N3100138,9),SETUP,MSGLEVEL=(1,1),REGION=250K,
//  TIME=(,15),USER=N310013,PASSWORD=CRD
// EXEC FTG1C,PARM.FORT='LOAD,NODECK,NOSOURCE'
//SYSIN DD *
C
C
C                            WAVE REFRACTION DIAGRAMS
C                  PROGRAM TO COMPUTE,PRINT,AND PLOT WAVE REFRACTION
C                                   DIAGRAMS
C
C                            DEFINITION OF INPUT PARAMETERS
C
C      AZIMTH - AZIMUTH OF  ,  AY.
C      BOUND  - DIMENSION I    DIRECTION OF PORTION OF MAP THAT WILL NOT
C               BE SHOWN ON PL  '. EXPRESSED IN INCHES AND ALWAYS IS
C               SUBTRACTED OFF DEEPWATER END.
C      CKDEP  - CHECK DEPTH. PROGRAM WILL PRINT RAY INFORMATION FOR THE
C               TIME STEP NEAREST THIS DEPTH.
C      DATE1  - DATE OF HYDROGRAPHIC CHART
C      DCON   - CONVERSION FACTOR FOR DEPTH VALUES TO FEET.
C      DELTAS - MINIMUM STEP LENGTH, EXPRESSED AS FRACTION OF GRID
C               SQUARE.
C      DEP    - WATER DEPTHS AT EACH GRID POINT.
C      DF     - FACTOR TO CONVERT DEPTH VALUES FROM ONE WATER SURFACE
C               DATUM TO ANOTHER. THE FACTOR WILL BE ADDED TO THE DEPTH
C               VALUE. IF NOT NEEDED LEAVE BLANK.
C      DGXL   - LENGTH OF WINDOW (X DIMENSION) EXPRESSED IN INCHES.
C      DGYL   - HEIGHT OF WINDOW (Y DIMENSION) EXPRESSED IN INCHES.
C      FAC    - SCALING FACTOR BY WHICH ALL POINTS ARE MULTIPLIED
C               BEFORE BEING PLOTTED.
C      GRID   - DIMENSION OF A SIDE OF A GRID SQUARE, EXPRESSED IN
C               MAP FEET.
C      GRINC  - DEEPWATER STEP LENGTH, EXPRESSED AS FRACTION OF GRID
C               SQUARE.
C      HO     - DEEPWATER WAVE HEIGHT
C      ISP    - SETS PRINT OPTION ON CHECK DEPTH. IF =-1,PROGRAM WILL
C               PROVIDE WAVE RAY INFORMATION AT TIME STEP NEAREST
C               CHECK DEPTH AND CONTINUE PROCESSING OF RAY; IF = 0,
C               PROGRAM DOES NOT LOOK FOR CHECK DEPTH; AND IF = 1,
C               PROGRAM PROVIDES DESIRED INFORMATION AND STOPS
C               PROCESSING OF RAY.
C      ITITLE - ALPHANUMERIC TITLE TO APPEAR ON PRINTER OUTPUT AND PLOT
C               FOR JOB IDENTIFICATION.
C      IWR    - IF = 0, NEW WAVE INFO TO BE READ
C               IF = 1, WAVE INFO IS PREVIOUSLY READ INPUT
```

```
C      JPEN   - PEN POSITION WHEN MOVING TO A NEW PLOT POINT ON
C               SHORELINE.
C      LCK    - TELLS PROGRAM IF SET OF RAYS IS STARTING IN DEEP WATER.
C               IF = 0, RAYS ARE STARTING IN DEEP WATER AND INITIAL
C               ANGLE OF RAYS WILL BE DEEPWATER AZIMUTH; IF = 1, RAYS
C               ARE NOT STARTING IN DEEP WATER AND STARTING
C               AZIMUTH FOR EACH RAY MUST BE INPUT.
C      LIMNPT - MAXIMUM NUMBER OF TIME STEPS TO BE COMPUTED FOR A RAY.
C      LPLOT  - NUMBER OF TIME STEPS BETWEEN PLOT POINTS ON A RAY.
C      MEAS   - UNITS WHICH DEPTHS ARE EXPRESSED IN
C      MI     - NUMBER OF GRID POINTS IN X-DIRECTION.
C      MJ     - NUMBER OF GRID POINTS IN Y-DIRECTION.
C      NORAYS - NUMBER OF RAYS IN A SET.
C      NOSETS - NUMBER OF SETS OF RAYS TO BE PROCESSED.
C      NPRINT - PRINTING INTERVAL FOR TIME STEP INFORMATION.
C      PD     - MAXIMUM DEPTH AT WHICH THE PRINTOUT WILL BEGIN.
C               THIS IS A MEANS TO DECREASE THE NUMBER OF LINES
C               PRINTED BY PRINTING ONLY THE INFORMATION FROM
C               SHALLOW WATER. (FEET)
C      RK     - REFRACTION COEFFICIENT OF WAVE RAY AT STARTING
C               LOCATION.
C      RK1    - REFRACTION COEFFICIENT OF WAVE RAY AT THE TIME STEP
C               PREVIOUS TO STARTING LOCATION.
C      SCNV   - MAGNIFICATION OF WINDOW
C      SCX    - SCALE FACTOR OR LENGTH OF A SIDE OF A GRID SQUARE
C               EXPRESSED IN INCHES.
C      SK     - SHOALING COEFFICIENT FOR FIRST TIME STEP
C      SK1    - DEEPWATER SHOALING COEFFICIENT
C      STAZ   - DEEPWATER AZIMUTH OF A SET OF RAYS.
C      T      - WAVE PERIOD FOR A SET OF RAYS
C      THI    - CLOCKWISE ANGLE BETWEEN NORTH ON MAP AND Y-AXIS OF GRID.
C      UNIT   - TIME STEP
C      X      - X-COORDINATE FOR A RAY.
C      XSG    - X-COORDINATE OF LOWER LEFT CORNER OF A WINDOW.
C               SET EQUAL TO MI IF WINDOW IS NOT DESIRED.
C      XSLINE - X-COORDINATE FOR DEFINING A POINT ON SHORELINE.
C      Y      - Y-COORDINATE FOR A RAY.
C      YFA    - FACTOR ADDED TO THE Y-COORDINATE OF THE STARTING POINT OF
C               A RAY IN ORDER TO DECREASE THE AMOUNT OF DEEPWATER REGION
C               THE WAVE TRAVELS OVER, THEREBY DECREASING THE COMPUTATION
C               TIME.
C      YSG    - Y-COORDINATE OF LOWER LEFT CORNER OF A WINDOW.
C               LEAVE BLANK IF WINDOW IS NOT DESIRED.
C      YSLINE - Y-COORDINATE FOR DEFINING A POINT ON SHORELINE.
C      W      - WATER LEVEL AT ZERO CONTOUR
C      WPI    - NUMBER OF WAVE PERIODS BETWEEN TIC MARKS ON A RAY.
C
C
C
C             A WINDOW IS AN AREA INSIDE THE GRID BEING PROCESSED.
```

```
C               THIS WINDOW WOULD BE USED FOR CASES WHERE IT IS
C               DESIRED TO STUDY A PARTICULAR AREA IN GREATER DETAIL
C               BY USING A LARGER SCALE GRID. THE PROGRAM WILL TRACE
C               THE RAY THROUGH THE WINDOW AND PRINT OUT STARTING
C               INPUT PARAMETER FOR THE RAY ON THE LARGER SCALE GRID.
C
C
      COMMON DEP(20000),MI,MJ,SCX,SCALE,GRID,PD
      COMMON B1, B2, BOUND, CKDEP, CO, CXY, D(12), DCDH, DCON,
     1DELTAS, DRC, DTGR, DXY, F(6), GRINC,
     2H, HH, HO, ICN, IGO, IRET, ISP, JGO, KFIRST, KPLOT,
     3LIMNPT, LPLOT, NPRINT, NPT, PHX, PHY, R90, RADIUS, RAYNO,
     4RCCO, RHS, RK, SCNV, SIG, SK, SK1, T, THI, TOP,
     5V, WL, WLO, XP, XSG, XSGL, YP, YSG, YSGL
      COMMON HPREV,SKPREV,RKPREV,UBOT,UMID,ET,CGR,POW,PL,OS
      DIMENSION IDATE(2),ITITLE(10),JBUF(5000),LEGEND (15)
      DIMENSION LEG1 (11), LEG2 (6),MEAS (3)
      DIMENSION XC(400),YC(400),AAZ(400),RRK1(400),RRK(400)
      DATA HLEG/0.112/
      DATA LEG1/'WAVE',' PER','IOD=','    ',' SEC','S   ','DEEP','WATE',
     1  'R AZ','IMUT','H=  '/,
     2  LEG2/' DEG','REES','DATE',' PLO','TTED',':   '/
C          FORMAT STATEMENTS IN MAIN PROGRAM
   80 FORMAT (' ',I5,'  RAYS EXCEEDS THE MAX LIMIT OF 175')
   90 FORMAT (' ',' THE VALUE OF KPLOT IS TOO SMALL')
  100 FORMAT (10A4)
  110 FORMAT (4I5,3F10.4)
  120 FORMAT (8F10.5)
  130 FORMAT (I5)
  140 FORMAT (F5.0)
  160 FORMAT (2I5,6F10.2,F10.6)
  170 FORMAT (2I5,3F10.4,I5,2F10.3)
  171 FORMAT (I5)
  178 FORMAT (1A4,2X,3A4,2X,A4)
  180 FORMAT (1H-,2A4)
  190 FORMAT (' ',///,42X,'WAVE REFRACTION ANALYSIS      ',10A4)
  200 FORMAT ('1',///////,39X,'WAVE REFRACTION PROGRAM--COASTAL',
     1' RESEARCH DIVISION')
  210 FORMAT (//,' MI=',I4,13X,'MJ=',I4,13X,'LIMNPT=',
     1  I5,8X,'NPRINT=',I4,9X,'GRID=',F10.4,5X,'DCON=',F10.4/' DELTAS=',
     2  F5.3)
  220 FORMAT    (8H0SET NO.,I3,10H,  RAY NO.,I3,10H,  PERIOD=,F7.3,
     1          6H SECS.)
  230 FORMAT   (8H GRINC =,F10.6,14H,  TIME STEP =,F8.3,7H SECS.,,
     1          24H  WAVE FRONT INCREMENT =,F7.2,6H SECS.)
  240 FORMAT(/'  POINT    X',5X,'Y',2X,'AZIMUTH DEPTH LENGTH SPEED  RK',
     1 5X,'SK',4X,'HEIGHT UMID  UBOT',4X,'TOTAL',6X,'GROUP',
     2 4X,'TOTAL    LONGSHORE',' DIR',/,' ',79X,'ENERGY',4X,
     3 'VELOCITY',3X,'POWER',5X,'POWER'/,
     4 I6,F7.1,2F6.1,6X,F7.1,F6.1,14X,F7.2)
```

```
  250 FORMAT ('1','MI * MJ EXCEEDS 20000')
  270 FORMAT (//,34H ALL SETS COMPLETED, NO. OF SETS =,I4)
  280 FORMAT (////,' ROUND=',F5.1,9X,'SCX=',F10.5,6X,'XSG=',F6.2,10X,
     1  'YSG=',F6.2,10X,'SCNV=',F6.3,9X,'DGXL=',F5.2/' DGYL=',F5.2,10X,
     2  'SCALE=',F10.3,4X,'NOSETS=',I3)
  282 FORMAT (////,' LPLOT=',I5,9X,'NORAYS=',I5,8X,'T=',F5.2,13X,'HO=',
     1 F5.2,12X,'SK=',F5.2,12X,'SK1=',F5.2,/' THI=',F7.2,9X,'STAZ=',F7.2
     2  ,8X,'UNIT=',F8.2/' ISP=',I3,13X,'LCK=',I3,13X,'WPI=',F7.2,9X,
     3  'CKDEP=',F6.2,8X,'DF=',F5.2,12X,'IWR=',I3,/' PD=',F8.2,9X,
     4  'YFA=',F5.1)
  284 FORMAT (' ',/,72X,2A4)
  286 FORMAT (////////////////,' INPUT PARAMETERS :')
  288 FORMAT (/////,' MAP DATE: ',A4,10X,'DEPTH IN ',3A4)
 9980 FORMAT (4A4)
      SINH(DUM)=.5*(EXP(DUM)-(1./EXP(DUM)))
C        READ TITLE INFORMATION
      READ (5,100) ITITLE
      READ (5,140) FAC
      READ (5,178) DATE1,MEAS,W
      CALL DATE (IDATE)
C        READ GRID INFORMATION AND OTHER BASIC DATA
      READ(5,110) MI, MJ, LIMNPT, NPRINT, GRID, DCON, DELTAS
      IJMAX = MI * MJ
      IF (IJMAX.GT.20000) GO TO 290
      GO TO 300
  290 WRITE(6,250)
      STOP
C        READ PLOT INFORMATION
  300 READ(5,120) ROUND, SCX, XSG, YSG, SCNV, DGXL, DGYL
C        READ ALL DEPTH VALUES
      SCALE=GRID/SCX
C        SET ORIGIN FOR PLOTS
      CALL PLOTS (JBUF,5000,9)
      IF (FAC .EQ. 0.) FAC=1.
      CALL FACTOR (FAC)
      CALL PLOT (3.,2.,-3)
      CALL BOTTOM
      WRITE (6,200)
C        SET SOME INITIAL VALUES
      RHS=MI
      RHS=RHS-2.5
      TOP=MJ
      TOP=TOP-2.5
      XLIMIT=(MI-1)*SCX
      R90=1.570796327
C     PRINT TITLE AND GRID DATA
      WRITE(6,190) ITITLE
      WRITE (6,284) IDATE
      WRITE (6,286)
      WRITE (6,210) MI,MJ,LIMNPT,NPRINT,GRID,DCON,DELTAS
```

```
C         READ NUMBER OF SETS OF RAYS AND SHORELINE DATA
      READ 130,NOSETS
      WRITE (6,280) BOUND,SCX,XSG,YSG,SCNV,DGXL,DGYL,SCALE,NOSETS
  360 CONTINUE
C         PROCESS EACH SET
      XSLINE = 0.0
      YSLINE = 0.0
      DFF=0.
  380 DO 510 NOSET=1,NOSETS
      READ (10,9990,END=415) XSS, YSS, JPEN
 9990 FORMAT(3A4)
      XSLINE=XSS/GRID
      YSLINE=YSS/GRID
C         PLOT LOWER LEFT CORNER FOR A SET
      CALL PLOT (0.0, 1.0, 3)
      CALL PLOT(0., 1., 2)
      CALL PLOT(0., 0., 2)
      CALL PLOT(1., 0., 2)
      CALL PLOT(0., 0., 2)
      CALL PLOT (0.,0.,3)
      XSL=XSLINE*SCX
      YSL=YSLINE*SCX-BOUND
      CALL PLOT (XSL,YSL,3)
      GO TO 411
C         PLOT SHORLEINE FOR A SET
  410 CONTINUE
      READ (10,9990,END=415) XSS, YSS, JPEN
  411 LPEN=JPEN
      XHOLD = XSLINE
      YHOLD = YSLINE
      XSLINE=XSS/GRID
      YSLINE=YSS/GRID
      IF (JPEN - 1) 400,390,400
  390 LPEN=2
      CALL REFDIA (XSLINE, YSLINE, 2)
      CALL REFDIA (XHOLD,YHOLD,2)
  400 CALL REFDIA (XSLINE,YSLINE,LPEN)
      GO TO 410
  415 CONTINUE
      REWIND 10
C         PLOT LOWER LEFT CORNER OF WINDOW
  420 IF (XSG-RHS) 430,440,440
  430 CALL REFDIA(XSG,YSG,3)
      CALL REFDIA(XSG,YSG+1.,2)
      CALL REFDIA(XSG,YSG,2)
      CALL REFDIA(XSG+1.,YSG,2)
C         PLOT LOWER RIGHT CORNER OF WINDOW
      CALL REFDIA(XSG,YSG,2)
      XSGL=XSG+DGXL/SCX
      YSGL=YSG+DGYL/SCX
```

```
      CALL REFDIA(XSGL,YSG,3)
      CALL REFDIA(XSGL,YSG+1.,2)
      CALL REFDIA(XSGL,YSG,2)
      CALL REFDIA(XSGL-1.,YSG,2)
      CALL REFDIA(XSGL,YSG,2)
C        READ BASIC WAVE DATA FOR A SET
  440 READ(5,160) LPLOT, NORAYS, T, HO, SK, SK1, THI, STAZ,
     1 UNIT
      IF (NORAYS .GE. 400) GO TO 800
      SKPR=SK
      READ (5,170) ISP,LCK,WPI,CKDEP,DF,IWR,PD,YFA
      IF (IWR .EQ. 0) READ (5,171) IRED
      IF (IRED .NE. 25) IRED=5
      IF (PD .EQ. 0.) PD=DEP(1)*DCON+DF
      IF (NOSET .EQ. 1) WRITE(6,282) LPLOT,NORAYS,T,HO,SK,SK1,THI,
     *  STAZ,UNIT,ISP,LCK,WPI,CKDEP,DF,IWR,PD,YFA
      IF (NOSET .EQ. 1) WRITE(6,288) DATE1,MEAS
      IF (NOSET .EQ. 1) GO TO 445
      WRITE (6,200)
      WRITE(6,190) ITITLE
      WRITE (6,284) IDATE
      WRITE (6,286)
      WRITE (6,210) MI,MJ,LIMNPT,NPRINT,GRID,DCON,DELTAS
      WRITE (6,280) BOUND,SCX,XSG,YSG,SCNV,DGXL,DGYL,SCALE,NOSETS
      WRITE(6,282) LPLOT,NORAYS,T,HO,SK,SK1,THI,
     *  STAZ,UNIT,ISP,LCK,WPI,CKDEP,DF,IWR,PD,YFA
      WRITE(6,288) DATE1,MEAS
  445 CONTINUE
C        SET INITIAL VALUES FOR THE SET
      IF ((NOSET .GE. 2) .AND. (DF .EQ. DFF)) GO TO 340
      IF (NOSET .GE. 2) DF=DF-DFF
      IF (DF) 310,340,310
  310 DO 330 J = 1,IJMAX
      DEP (J) = DEP (J) + DF
  330 CONTINUE
  340 DFF=DFF+DF
      KSP=ISP
      SIG=6.28318531/T
      CO=5.120406*T
      WLO=CO*T
      DRC=WLO*0.5
      DTGR=UNIT/GRID
      GRINC=DTGR*CO
      WFI=T*WPI
      KPLOT=WFI/UNIT+0.1
      IF (KPLOT .EQ. 0) GO TO 810
C        PROCESS EACH RAY IN SET
      DO 500 NORAY=1,NORAYS
      HPREV=HO
      DS=GRINC
```

```
      KFIRST=0
      WRITE(6,180)IDATE
      ISP=KSP
      WRITE(6,220) NOSET, NORAY, T
      IF (LCK) 460,450,460
C        READ RAY DATA
  450 IF(IWR .EQ. 0) READ(IRED,120,END=501) XC(NORAY),YC(NORAY)
      IF (XC(NORAY) .LE. 0.) GO TO 501
      X=XC(NORAY)
      Y=YC(NORAY)+YFA
      AZIMTH=STAZ
      RK=1.0
      SK=1.
      B1=1.0
      B2=1.0
      RKPREV=1.
      SKPREV=1.
      GO TO 470
  460 IF(IWR .EQ. 0) READ(IRED,120,END=501) XC(NORAY),YC(NORAY),
     *  AAZ(NORAY),RRK(NORAY),RRK1(NORAY)
      IF (XC(NORAY) .LE. 0.) GO TO 501
      X=XC(NORAY)
      Y=YC(NORAY)+YFA
      AZIMTH=AAZ(NORAY)
      RK1=RRK1(NORAY)
      RK=RRK(NORAY)
      B1=1./RK1/RK1
      B2=1./RK/RK
      SK=SKPR
      SKPREV=1.
      RKPREV=1.
  470 A=THI+270.0-AZIMTH
C        SET INITIAL VALUES FOR RAY
      NPT=1
      CXY=CO
      WL=WLO
C        PRINT STEP AND TIME INFORMATION
      WRITE(6,230) GRINC, UNIT, WFI
      RAYNO=NORAY
      XNO=X*SCX
      YNO=Y*SCX-BOUND
      IF (YNO) 490,480,480
C        IDENTIFY RAY ON PLOT
  480 KFIRST=1
      CALL NUMBER (XNO,YNO-0.15,0.112,RAYNO,0.,-1)
      CALL REFDIA (X,Y,3)
C        PRINT DEEPWATER WAVE INFORMATION
  490 WRITE(6,240) NPT, X, Y, STAZ, WLO, CO, HO
C        CALL RAYCON TO COMPUTE,PRINT,AND PLOT THIS RAY
      CALL RAYCON (X,Y,A)
```

```
  500 CONTINUE
  501 CONTINUE
C         PRINT TITLE AND WAVE DATA ON PLOT
      XLEG=XLIMIT-6.72
      CALL SYMBOL (XLEG,-0.5,0.168,ITITLE,0.,40)
      CALL SYMBOL (XLEG, -1.,HLEG,LEG1(1)  , 0.,14)
      CALL NUMBER (999.,999.,0.112,T,0.,3)
      CALL SYMBOL (999.,999.,HLEG,LEG1(5)  ,0.,5)
      CALL SYMBOL (XLEG,-1.25,HLEG,LEG1(7)  ,0.,20)
      CALL NUMBER (999.,999.,0.112,STAZ,0.,1)
      CALL SYMBOL (999.,999.,HLEG,LEG2(1)   ,0.,8)
      CALL SYMBOL (XLEG,-1.50,HLEG,LEG2(3)   ,0.,15)
      CALL SYMBOL (999.,999.,.112,IDATE,0.,8)
      CALL SYMBOL (XLEG+4.,-1.,HLEG,'0 CONTOUR AT ',0.,13)
      CALL SYMBOL (999.,999.,HLEG,W,0.,4)
      CALL SYMBOL (XLEG+4.,-1.25,HLEG,'RELATIVE WATER LEVEL= ',0.,22)
      CALL NUMBER (999.,999.,HLEG,DFF,0.,2)
      CALL SYMBOL (XLEG+7.,-1.25,HLEG,MEAS,0.,12)
      CALL SYMBOL (XLEG+4.,-1.50,HLEG,'MAP DATE: ',0.,10)
      CALL SYMBOL (999.,999.,HLEG,DATE1,0.,4)
      CALL SYMBOL(XLEG,-1.75,HLEG,'DEEPWATER WAVE HEIGHT= ',0.,23)
      CALL NUMBER(999.,999.,HLEG,H0,0.,2)
      CALL SYMBOL(999.,999.,HLEG,' FEET',0.,5)
C         DRAW LOWER RIGHT CORNER OF PLOT FOR A SET
      CALL PLOT (XLIMIT,0.,3)
      CALL PLOT (XLIMIT,1.,2)
      CALL PLOT (XLIMIT,0.,2)
      CALL PLOT (XLIMIT -1.,0.,2)
      CALL PLOT (XLIMIT,0.,2)
      CALL PLOT (XLIMIT,0.,3)
      IST =1
      IST1=0
  511 REWIND 11
  509 CONTINUE
      READ (11,9980,END=790) XS,YS,DEPTH,IPN
      XX=XS*SCX/GRID
      YY=YS*SCX/GRID
      IF (YY .LT. BOUND) GO TO 509
      YY=YY-BOUND
      HDEPTH=DEPTH
      IPEN=3
      GO TO 730
  600 READ (11,9980,END=770) XS,YS,DEPTH,IPN
      IF (DEPTH .LE. 0.) GO TO 600
      IF (IPH .EQ. IPN) GO TO 650
      IPH=2
      HDEPTH=DEPTH
      CALL PLOT (XH,YH,IPEN)
      IPEN=3
      IST=1
```

```
      IST1=0
      CALL PLOT (XH,YH,IPEN)
  650 XX=XS*SCX/GRID
      YY=YS*SCX/GRID
      IF (YY .LT. BOUND) GO TO 665
      YY=YY-BOUND
      IF (IST1 .EQ. 0) GO TO 670
      IF (XX .LT. XXH) GO TO 660
      IF (XX .GT. XXH+SIZE) GO TO 660
      IF (YY .GT. YYH+.06) GO TO 660
      IF (YY .LT. YYH-.06) GO TO 660
      IPEN=3
      GO TO 600
  660 CONTINUE
      IST =0
      GO TO 680
  665 IPH=3
      GO TO 600
  670 IF (IST .EQ. 0) GO TO 680
      IST1=1
      IST=0
      ADPTH=-DEPTH
      DPTH=ABS(DEPTH)
      SIZE=3.
      IF (DPTH .GE. 1.) SIZE=SIZE+1.
      IF(DPTH .GE. 10.) SIZE=SIZE+1.
      IF(DPTH .GE. 100.) SIZE=SIZE+1.
      IF(DPTH .GE. 1000.) SIZE=SIZE+1.
      IF (DEPTH .GT. 0.) SIZE=SIZE+1.
      SIZE=SIZE*.09
      IF (XX .GE. FLOAT(MI-3)*SCX) GO TO 675
      CALL NUMBER (XX+.035,YY-.035,.10,ADPTH,0.,1)
      XXH=XX
      YYH=YY
      GO TO 600
  675 CONTINUE
      XXX=XX-SIZE
      CALL NUMBER (XXX,YY-.035,.10,ADPTH,0.,1)
      XXH=XXX
      YYH=YY
      GO TO 600
  680 CONTINUE
  730 CALL PLOT (XX,YY,IPEN)
      IPEN=2
      XH=XX
      YH=YY
      GO TO 600
  770 CALL PLOT (XX,YY,3)
  790 CONTINUE
C         SET ORIGIN FOR A NEW PLOT
```

```
      CALL PLOT (XLIMIT+3.,0.,-3)
  510 CONTINUE
      WRITE(6,270) NOSETS
      GO TO 820
  800 WRITE(6,80) NORAYS
      GO TO 820
  810 WRITE (6,90)
  820 CALL PLOT (0.,0.,999)
      STOP
      END
```

```
C         RAYCON SUBROUTINE DECK
C         CONTROLS COMPUTATIONS,PRINTING,AND PLOTTING OF EACH RAY
      SUBROUTINE RAYCON(X,Y,A)
         COMMON DEP(20000),MI,MJ,SCX,SCALF,GRID,PD
      COMMON H1, H2, BOUND, CKDEP, CO, CXY, D(12), DCDH, DCON,
     1DELTAS, DRC, DTGR, DXY, E(6), GRINC,
     2 H, HH, HO, ICN, IGO, IRET, ISP, JGO, KFIRST, KPLOT,
     3 LIMNPT, LPLOT, NPRINT, NPT, PHX, PHY, R90, RADIUS, RAYNO,
     4RCCO, RHS, RK, SCNV, SIG, SK, SK1, T, THI, TOP,
     5 V, WL, WLO, XP, XSG, XSGL, YP, YSG, YSGL
      COMMON HPREV,SKPREV,RKPREV,UEOT,UMID,ET,CGR,POW,PL,DS
      COMMON IDIR
      DIMENSION R(16)
  100 FORMAT(' ',I5,'*',4F6.1,F7.1,F6.1,2F7.3,F7.2,2F6.2,4F10.2,3X,A1)
  110 FORMAT(' ',I5,F7.1,3F6.1,F7.1,F6.1,2F7.3,F7.2,2F6.2,4F10.2,3X,A1)
  120 FORMAT (28H CURVATURE AVERAGED AT POINT,I4)
  130 FORMAT (34H RAY INSIDE DETAILED GRID AT POINT,I4,11H  DETAILED
     1        29H GRID STARTING LOCATION IS X=,F7.2,4H  Y=,F7.2)
  140 FORMAT (/,42H RAY STOPPED, NO CONVERGENCE FOR CURVATURE)
  150 FORMAT (/,31H RAY STOPPED, WAVE BREAKS AT X=,F7.2,4H  Y=,F7.2)
  160 FORMAT (/,33H RAY STOPPED, REACHED BOUNDARY X=,F7.2,4H  Y=,F7.2)
  170 FORMAT (/,32H RAY STOPPED, LIMNPT EXCEEDED X=,F7.2,4H  Y=,F7.2)
  180 FORMAT (/,34H RAY STOPPED, DELTA'S TOO SMALL X=,F7.2,4H  Y=,F7.2)
  190 FORMAT (9H RAY NEAR, F6.2,14H FOOT CONTOUR )
C
C     IF THE RAY STARTS IN WATER LESS THAN BREAKER DEPTH GO TO THE NEXT
C
      ANEX=A*.0174532925
      XNEX=COS(A)*GRINC+X
      YNEX=SIN(A)*GRINC+Y
      CALL DEPTH(XNEX,YNEX)
      IF (.8*DXY-HO) 492,492,494
  492 WRITE (6,289)
  289 FORMAT ('0','RAY STARTS TOO CLOSE TO SHORE')
      RETURN
  494 CONTINUE
      END=0.
      IF (XSG-RHS) 200,210,210
  200 LFIRST=0
      SGX=XSG+1.5/SCNV
      SGY=YSG+1.5/SCNV
      SGXX=XSGL-1.5/SCNV
      SGYY=YSGL-1.5/SCNV
      GO TO 220
  210 LFIRST=1
C         SET INITIAL VALUES USED TO START A RAY
  220 LPRINT=0
```

```
      FLAG1=0.0
      ANG=THI+270.0-A
      A=A*0.0174532925
      COSA=COS(A)
      SINA=SIN(A)
      H=HO
      IGO=1
C        SAVE VALVES OF X AND Y
  230 PX=X
      PY=Y
C        ADVANCE X AND Y ONE STEP AND FIND NEW DEPTH
      X=COSA*GRINC+X
      Y=SINA*GRINC+Y
      CALL DEPTH(X,Y)
      NWRITE=1
C        CHECK TO SEE IF WAVE HEIGHT IS GREATER THAN .8 OF WATER DEPTH
      IF(.8*DXY-H) 380,380,240
C        NO, CHECK TO SEE IF RAY IS IN DEEP WATER
  240 IF(DXY-DRC) 320,320,250
C        YES, ADVANCE STEP COUNT AND CHECK TO SEE IF LIMNPT IS EXCEEDED
  250 NPT=NPT+1
      CALL FRICTN
      IF(LIMNPT-NPT) 400,400,260
C        NO. CHECK TO SEE IF RAY IS TOO CLOSE TO BOUNDARY
  260 IF(RHS-X) 270,270,280
C        YES. SET TO PRINT OUT RAY TOO CLOSE TO BOUNDARY
  270 IRET=5
      GO TO 350
  280 IF(X-1.5) 270,270,290
  290 IF(TOP-Y) 270,270,300
  300 IF(Y-1.5) 270,270,310
C        RAY WITHIN BOUNDARY AND IN DEEP WATER. GO TO
C        CHECK PRINTING AND PLOTTING OPTIONS
  310 GO TO 480
C        RAY WITHIN BOUNDARY BUT NOT IN DEEP WATER
  320 X=PX
      Y=PY
C        COMPUTE CURVATURE OF RAY IN FIRST STEP AFTER DEEP WATER
      CALL CURVE(X,Y,A,FK)
C        ADVANCE STEP COUNTER AND CHECK TO SEE IF LIMNPT IS EXCEEDED
  330 NPT=NPT+1
      IF(NPT-LIMNPT) 340,400,400
  340 NWRITE=1
C        COMPUTE X AND Y COORDINATES AND ANGLE OF RAY FOR NEW STEP
      FLAG1=1.0
      CALL REFRAC(X,Y,A,FK)
C        GO TO CONDITION CONTROLLED BY VALUE OF IRET
  350 GO TO (410,380,370,360,390,420),IRET
C        SET NWRITE FOR STATUS OF RAY
  360 NWRITE=2
```

```
      GO TO 420
  370 NWRITE=3
      GO TO 420
  380 NWRITE=4
      IF (FLAG1 .EQ. 0.0) GO TO 492
      GO TO 420
  390 NWRITE=5
      GO TO 730
  400 NWRITE=6
      GO TO 730
  410 NWRITE=7
      GO TO 730
C        COMPUTE REFRACTION AND SHOALING COEFFICIENTS AND WAVE HEIGHT
  420 CALL HEIGHT(A)
      IF(DXY-CKDEP) 430,430,460
  430 IF(ISP) 450,470,440
  440 IGO=3
  450 ISP=0
      NWRITE=9
      GO TO 470
  460 IF(ISP) 470,470,740
  470 IF(NWRITE-1) 480,480,490
C        CHECK PRINT OPTION AND SET
  480 IF(MOD(NPT,NPRINT)) 500,490,500
  490 LPRINT=1
C        HAS NUMBER BEEN PLACED ON THIS RAY
  500 IF(KFIRST) 530,510,530
C        IS THIS STEP WITHIN STARTING PLOT BOUNDARY)
  510 YON=Y*SCX-BOUND
      IF(YON) 700,520,520
C        YES, PLOT THE RAY NUMBER, SET TO NO AND PEN UP,AND GO TO PRINT
  520 CALL NUMBER(X*SCX,YON-0.15,0.112,RAYNO,0.,-1)
      KFIRST=1
      CALL REFDIA (X,Y,3)
C        CHECK TO SEE IF RAY REACHED DETAILED GRID ON ANY PREVIOUS STEP
  530 IF (LFIRST) 590,540,590
C        NO, IS RAY WITHIN DETAILED GRID ON THIS STEP
  540 IF(X-SGX) 590,550,550
  550 IF(X-SGXX) 560,560,590
  560 IF(Y-SGY) 590,570,570
  570 IF(Y-SGYY) 580,580,590
C        YES, SET NWRITE FOR THIS CONDITION
  580 NWRITE=8
      LFIRST=1
      LPRINT=1
C        COMPUTE DETAILED GRID STARTING POSITION
      DGX=(X-XSG)*SCNV
      DGY=(Y-YSG)*SCNV
C        STEP WITHIN BOUNDARY, IS TIC MARK TO BE PLOTTED ON RAY
  590 IF(MOD(NPT,KPLOT)) 600,620,600
```

```
C          NO, IS STEP TO BE PLOTTED
  600 IF(MOD(NPT,LPLOT)) 700,610,700
C          YES, PLOT STEP AND GO TO PRINT
  610 CALL REFDIA(X,Y,2)
      GO TO 700
C          TIC MARK TO BE PLOTTED PERPENDICULAR TO RAY,
C          COMPUTE ANGLE AND AZIMUTH IN DEGREES
  620 AA=A*57.29578
      ANG=THI+270.0-AA
C          SET TO PLACE ASTERISK ON PRINT OUT BY THIS STEP
      LPRINT=-1
      CALL REFDIA(X,Y,2)
C          FIND QUADRANT THAT RAY IS IN AND COMPUTE TIC MARK COORDINATES
      IF(AA-90.) 630,630,640
  630 YTIC=0.05*SIN(R90-A)
      XTIC=0.05*SIN(A)
      GO TO 690
  640 IF(AA-180.) 650,650,660
  650 YTIC=-0.05*SIN(A-R90)
      XTIC=0.05*SIN(3.141592654-A)
      GO TO 690
  660 IF(AA-270.) 670,670,680
  670 YTIC=0.05*SIN(A-3.141592654)
      XTIC=0.05*SIN(4.712388981-A)
      GO TO 690
  680 YTIC=-0.05*SIN(A-4.712388981)
      XTIC=0.05*SIN(6.283185308-A)
C          PLOT TIC MARKS
  690 CALL REFDIA (X+XTIC,Y-YTIC,2)
      CALL REFDIA(X-XTIC,Y+YTIC,2)
      CALL REFDIA(X,Y,2)
C          CHECK PRINT OPTION
  700 IF(LPRINT) 710,740,720
C          PRINT STEP INFORMATION WITH ASTERISK BY STEP NUMBER TO DENOTE
C          THAT A TIC MARK WAS MADE PERPENDICULAR TO RAY ON PLOT
  710 CONTINUE
      CALL ENERGY (A,END)
      IF (DXY .LE. PD)
    & WRITE(6,100) NPT,X,Y,ANG,DXY,WL,CXY,RK,SK,H,UMID,UROT,ET,
    & CGR,POW,PL,IDIR
C          RESET PRINT OPTION TO NO PRINT AND GO TO CHECK STATUS OF RAY
      LPRINT=0
      GO TO 740
C          COMPUTE RAY AZIMUTH IN DEGREES AND PRINT STEP INFORMATION
  720 ANG=THI+270.0-A*57.29578
      CALL ENERGY (A,END)
      IF (DXY .LE. PD)
    & WRITE(6,110) NPT,X,Y,ANG,DXY,WL,CXY,RK,SK,H,UMID,UROT,ET,
    & CGR,POW,PL,IDIR
C          RESET PRINT OPTION TO NO PRINT AND GO TO CHECK STATUS OF RAY
```

```
      LPRINT=0
      GO TO 740
C        LAST STEP OF A RAY
C        COMPUTE RAY AZIMUTH IN DEGREES AND PRINT STEP INFORMATION
  730 ANG=THI+270.0-A*57.29578
      WRITE(6,110) NPT,X,Y,ANG,DXY
C        PLOT LAST STEP OF RAY
      CALL REFDIA(X,Y,2)
C        GO TO CONDITION CONTROLLED BY VALUE OF NWRITE
  740 GO TO (830,750,760,770,780,790,800,820,850),
     1 NWRITE
C        PRINT PROGRAM MESSAGE AND CONTINUE RAY COMPUTATIONS
  750 WRITE(6,120) NPT
      GO TO 830
C        PRINT PROGRAM ERROR MESSAGE AND STOP RAY COMPUTATIONS
  760 WRITE(6,140)
      GO TO 810
  770 WRITE(6,150) X,Y
      CALL REFDIA (X,Y,2)
      END=1.
      CALL ENERGY(A,END)
      END=0.
      GO TO 810
  780 WRITE(6,160) X,Y
      GO TO 810
  790 WRITE(6,170) X,Y
      GO TO 810
  800 WRITE(6,180) X,Y
  810 IGO=3
      GO TO 830
  820 WRITE(6,130) NPT,DGX,DGY
      IWRIT=7
      WRITE (IWRIT,135) DGX,DGY,ANG,RK,RKPREV
  135 FORMAT(3F10.2,2F10.4)
C        CHECK STATUS OF RAY AND BRANCH TO PROPER CONDITION
  830 GO TO (230,330,840),IGO
  840 RETURN
  850 WRITE(6,190) CKDEP
      GO TO 830
      END
```

```
C         REFRAC SUBROUTINE DECK
C         COMPUTES CURVATURE OF RAY IN A NEW STEP
C         CHECKS TO SEE IF RAY HAS REATCHED BOUNDARY
      SUBROUTINE REFRAC(X,Y,A,FK)
            COMMON DEP(20000),MI,MJ,SCX,SCALE,GRID,PD
      COMMON B1, B2, BOUND, CKDEP, CO, CXY, D(12), DCDH, DCON,
     1DELTAS, DRC, DTGR, DXY, E(6), GRINC,
     2 H, HH, HO, ICN, IGO, IRET, ISP, JGO, KFIRST, KPLOT,
     3 LIMNPT, LPLOT, NPRINT, NPT, PHX, PHY, R90, RADIUS, RAYNO,
     4RCCO, RHS, RK, SCNV, SIG, SK, SK1, T, THI, TOP,
     5 V, WL, WLO, XP, XSG, XSGL, YP, YSG, YSGL
      COMMON HPREV,SKPREV,RKPREV,UBOT,UMID,ET,CGR,POW,PL,DS
      DIMENSION RF(9)
C         SET INITIAL VALUE FOR NO AVERAGE OF CURVATURE
      NCUR=1
C         GO TO CONDITION CONTROLLED BY VALUE OF IGO
      GO TO (100,110,350),IGO
C         FIRST TIME THROUGH SUBROUTINE, SET FOR THIS CONDITION
  100 FKM=FK
      IGO=2
C         COMPUTE STEP LENGHT
  110 DS=CXY*DTGR
C         IS STEP LENGTH SMALLER THAN PRESCRIBED MINIMUM VALUE
      IF(DS-DELTAS) 120,130,130
C         YES, SET IRET FOR THIS CONDITION AND RETURN TO RAYCON
  120 IRET=1
      RETURN
C         NO. COMPUTE TEST FOR CONVERGENCE OF CURVATURE
  130 RESMAX=0.00005/DS
C         DO A MAXIMUN OF 20 ITERATIONS TO COMPUTE NEW STEP
  140 DO 210 I=1,20
C         COMPUTE DELTA ANGLE FOR NEW STEP TRIAL
      DELA=FKM*DS
C         COMPUTE TRIAL ANGLE AND COORDINATES
      AA=A+DELA
      AM=DELA*0.5+A
      XX=COS(AM)*DS+X
      YY=SIN(AM)*DS+Y
C         COMPUTE CURVATURE OF RAY FOR TRIAL
      CALL CURVE(XX,YY,AA,FKK)
C         WILL WAVE BREAK IN TRIAL STEP
      IF(.8*DXY-H) 150,150,160
C         YES, SET IRET FOR THIS CONDITION AND RETURN TO RAYCON
  150 IRET=2
      RETURN
C         NO, WAS CURVATURE AVERAGED IN LAST SOLUTION
  160  GO TO (170,240), NCUR
```

```
C          NO. COMPUTE AVERAGE CURVATURE OF THIS TRIAL STEP
  170  FKM=(FK+FKK)*0.5
C          IS THIS FIRST ITERATION
      IF(I-1) 210,210,180
C          NO. IS CONVERGENCE TEST SATISFIED
  180 IF(RESMAX-ABS(FKP-FKM))190,190,240
C          NO. IS THIS THE 18TH ITERATION
  190  IF(I-18) 210,200,210
C          YES. SET DUMMY VARIABLE TO USE IN AVERAGING RAY CURVATURE
  200  FKCK=FKM
C          CONVERGENCE TEST NOT SATISFIED
C          SAVE CURVATURE FOR THIS TRIAL AND IF NOT 20TH START NEW TRIAL
  210  FKP=FKM
C          CONVERGENCE TEST NOT SATISFIED AFTER 20 ITERATIONS
C          IS CONVERGENCE TEST SATISFIED BETWEEN 18TH AND 20TH ITERATIONS
      IF(RESMAX-ABS(FKCK-FKM)) 220,220,230
C          NO. SET IRET FOR NO CONVERGENCE AND RETURN TO RAYCON
  220  IRET=3
      RETURN
C          YES. SET CURVATURE EQUAL TO AVERAGE OF 18TH AND 20TH
C          ITERATION AND SET
  230  FKM=(FKM+FKCK)*0.5
      NCUR=2
C          CURVATURE IS COMPUTED. SET VALUES OF NEW STEP TO RETURN
      GO TO 140
  240 X=XX
      Y=YY
      A=AA
      FK=FKK
      IF(NCUR-2) 260,250,260
  250  IRET=4
      RETURN
  260  IF(RHS-X) 270,270,280
  270  IRET=5
      RETURN
  280 IF(X-1.5) 290,290,300
  290  IRET=5
      RETURN
  300  IF(TOP-Y) 310,310,320
  310  IRET=5
      RETURN
  320  IF(Y-1.5) 330,330,340
  330  IRET=5
      RETURN
  340  IRET=6
  350  RETURN
      END
```

```
C         CURVE SUBROUTINE DECK
      SUBROUTINE CURVE(X,Y,A,FK)
              COMMON DEP(20000),MI,MJ,SCX,SCALE,GRID,PD
      COMMON B1,B2,BOUND, CKDEP, CO, CXY, D(12), DCDH, DCON,
     1DELTAS, DRC, DTGR, DXY, E(6), GRINC,
     2 H, HH, HO, ICN, IGO, IRET, ISP, JGO, KFIRST, KPLOT,
     3 LIMNPT, LPLOT, NPRINT, NPT, PHX, PHY, R90, RADIUS, RAYNO,
     4RCCO, RHS, RK, SCNV, SIG, SK, SK1, T, THI, TOP,
     5 V, WL, WLO, XP, XSG, XSGL, YP, YSG, YSGL
      COMMON HPREV,SKPREV,RKPREV,UBOT,UMID,ET,CGP,POW,PL,DS
      GO TO (140,100), IGO
  100  CALL DEPTH (X,Y)
      IF (DXY*200.0-WL) 110,140,140
  110 IF (DXY) 120,120,130
  120 RETURN
  130  JGO=2
      ARG=32.1725*(DXY)
      CXY=SQRT(ARG)
      DCDH=16.08625/CXY
      GO TO 170
  140 CI=CXY
      JGO=1
      DO 150 I=1,50
      ARG=((DXY)*SIG)/CI
      ARG=TANH(ARG)
      CXY=CO*ARG
      IF (ABS(CXY-CI)-0.0001) 160,150,150
  150 CI=(CXY+CI)*0.5
  160 RCCO=CXY/CO
      SCMC=(1.0-RCCO*RCCO)*SIG
      V=SCMC*(DXY)+RCCO*CXY
      DCDH=CXY*SCMC/V
  170 PHX=E(4)*2.0*XP+E(5)*YP+E(2)
      PHY=E(6)*2.0*YP+E(5)*XP+E(3)
      FK=(SIN(A)*PHX-COS(A)*PHY)*DCDH*DCON/CXY
      RETURN
      END
```

```
C        DEPTH SUBROUTINE DECK
      SUBROUTINE DEPTH (X,Y)
      COMMON DEP(20000),MI,MJ,SCX,SCALE,GRID,PD
      COMMON B1, B2, BOUND, CKDEP, CO, CXY, D(12), DCDH, DCON,
     1DELTAS, DRC, DTGR, DXY, E(6), GRINC,
     2 H, HH, HO, ICN, IGO, IRET, ISP, JGO, KFIRST, KPLOT,
     3 LIMNPT, LPLOT, NPRINT, NPT, PHX, PHY, R90, RADIUS, RAYNO,
     4RCCO, RHS, RK, SCNV, SIG, SK, SK1, T, THI, TOP,
     5 V, WL, WLO, XP, XSG, XSGL, YP, YSG, YSGL
      COMMON HPREV,SKPREV,RKPREV,UBOT,UMID,FT,CGR,POW,PL,DS
      DIMENSION S(12,6)
      S(1,1)=0.30861241
      S(2,1)=0.23684207
      S(3,1)=0.21770331
      S(4,1)=0.23684207
      S(5,1)=-0.08492823
      S(6,1)=-0.05143541
      S(7,1)=-0.05143541
      S(8,1)=-0.08492823
      S(9,1)=0.00598086
      S(10,1)=0.13038277
      S(11,1)=0.13038277
      S(12,1)=0.00598086
      S(1,2)=0.05322964
      S(2,2)=0.19677030
      S(3,2)=0.14413872
      S(4,2)=0.10586122
      S(5,2)=0.09031100
      S(6,2)=-0.06758374
      S(7,2)=-0.03349283
      S(8,2)=0.03349282
      S(9,2)=-0.18241626
      S(10,2)=-0.34031099
      S(11,2)=-0.12440190
      S(12,2)=0.12440190
      S(1,3)=0.05322964
      S(2,3)=0.10586122
      S(3,3)=0.14413872
      S(4,3)=0.19677030
      S(5,3)=0.03349282
      S(6,3)=-0.03349282
      S(7,3)=-0.06758374
      S(8,3)=0.09031099
      S(9,3)=0.12440190
      S(10,3)=-0.12440191
      S(11,3)=-0.34031099
      S(12,3)=-0.18241625
```

```
      S(1,4)=-0.12499998
      S(2,4)=-0.12499998
      S(3,4)=-0.12499998
      S(4,4)=-0.12499998
      S(5,4)=0.125
      S(6,4)=0.125
      S(7,4)=0.0
      S(8,4)=0.0
      S(9,4)=0.12499999
      S(10,4)=0.1249999
      S(11,4)=-0.0
      S(12,4)=-0.0
      S(1,5)=0.05263157
      S(2,5)=-0.05263157
      S(3,5)=0.05263158
      S(4,5)=-0.05263157
      S(5,5)=-0.15789473
      S(6,5)=0.15789474
      S(7,5)=0.15789474
      S(8,5)=-0.15789473
      S(9,5)=-0.15789473
      S(10,5)=0.15789473
      S(11,5)=0.15789473
      S(12,5)=-0.15789473
      S(1,6)=-0.12499998
      S(2,6)=-0.12499998
      S(3,6)=-0.12499998
      S(4,6)=-0.12499998
      S(5,6)=0.0
      S(6,6)=0.0
      S(7,6)=0.125
      S(8,6)=0.125
      S(9,6)=-0.0
      S(10,6)=-0.0
      S(11,6)=0.12499999
      S(12,6)=0.12499999
      I=X+1.
      J=Y+1.
      XP=AMOD(X,1.)
      YP=AMOD(Y,1.)
      IF(NPT-1) 120,120,100
  100 IF(IP-I) 120,110,120
  110 IF(JP-J) 120,150,120
  120 IP=I
      JP=J
      I=JP
      J=IP
      IIAX = (I - 1) * MI
      D(1) = DEP (IIAX + J)
      D(2) = DEP (IIAX + J + 1)
```

```
      D(3) = DEP (IIAX + MI + J + 1)
      D(4) = DEP (IIAX + MI + J)
      D(5) = DEP (IIAX + J + 2)
      D(6) = DEP (IIAX + MI + J + 2)
      D(7) = DEP (IIAX + 2 * MI + J + 1)
      D(8) = DEP (IIAX + 2 * MI + J)
      D(9) = DEP (IIAX + MI + J - 1)
      D(10) = DEP (IIAX + J - 1)
      D(11) = DEP (IIAX - MI + J)
      D(12) = DEP (IIAX - MI + J + 1)
      DO 140 K=1,6
      SUM=0.
      DO 130 L=1,12
      SUM=SUM+D(L)*S(L,K)
  130 CONTINUE
      E(K)=SUM
  140  CONTINUE
  150 DXY=(E(1)+E(2)*XP+E(3)*YP+E(4)*XP *XP+
     1 E(5)*XP*YP+E(6)*YP*YP)*DCON
      RETURN
      END
```

```
C        REFRACTION COEFF SUBROUTINE DECK
      SUBROUTINE HEIGHT(A)
      COMMON DEP(20000),MI,MJ,SCX,SCALE,GRID,PD
      COMMON B1, B2, BOUND, CKDEP, CO, CXY, U(12), DCDH, DCON,
     1DELTAS, DRC, DTGR, DXY, E(6), GRINC,
     2 H, HH, HO, ICN, IGO, IRET, ISP, JGO, KFIRST, KPLOT,
     3 LIMNPT, LPLOT, NPRINT, NPT, PHX, PHY, R90, RADIUS, RAYNO,
     4RCCO, RHS, RK, SCNV, SIG, SK, SK1, T, THI, TOP,
     5 V, WL, WLO, XP, XSG, XSGL, YP, YSG, YSGL
      COMMON HPREV,SKPREV,RKPREV,UBOT,UMID,ET,CGR,POW,PL,DS
      SKPREV=SK
      RKPREV=RK
      WL=WLO*RCCO
      GN=12.566370614*DXY/WL
      HS1=EXP(GN)
      HS2=1./HS1
      CG=(1.+GN/(HS1-HS2)*2.)*CXY
      IF (CG) 100,110, 110
  100  RETURN
  110 CONTINUE
      RK=ABS(1.0/B2)
      SK=SQRT(CO/CG)
      RK=SQRT(RK)
      H=(HO*SK*RK)/SK1
      GO TO (120,130), JGO
  120 U=-2.0*SIG*RCCO*CXY/(V*V)
      GO TO 140
  130 U=-0.5/DXY
  140 U=U*DCON
      DCDH=DCDH*DCON
      COSA=COS(A)
      SINA=SIN(A)
      P=-(COSA*PHX+SINA*PHY)*DCDH*DTGR*2.0
      Q=((E(4)*2.0+U*PHX*PHX)*SINA*SINA-(E(5)+
     1 U*PHX*PHY)*2.0*SINA*COSA+(E(6)*2.0+U*
     2 PHY*PHY)*COSA*COSA)*DCDH*CXY*DTGR*DTGR*
     3 2.0
      B3=((P-2.0)*B1+(4.0-Q)*B2)/(P+2.0)
      B1=B2
      B2=B3
      CALL FRICTN
      RETURN
      END
```

```
C
C        SUBROUTINE TO PLOT WAVE RAYS
C
      SUBROUTINE REFDIA(XR,YR,IPEN)
      COMMON DEP(20000),MI,MJ,SCX,SCALE,GRID,PD
      COMMON B1, B2, BOUND, CKDEP, CO, CXY, D(12), DCDH, DCON,
     1DELTAS, DRC, DTGR, DXY, E(6), GRINC,
     2 H, HH, HO, ICN, IGO, IRET, ISP, JGO, KFIRST, KPLOT,
     3 LIMNPT, LPLOT, NPRINT, NPT, PHX, PHY, R90, RADIUS, RAYNO,
     4RCCO, RHS, RK, SCNV, SIG, SK, SK1, T, THI, TOP,
     5 V, WL, WLO, XP, XSG, XSGL, YP, YSG, YSGL
      COMMON HPREV,SKPREV,RKPREV,UBOT,UMID,ET,CGR,POW,PL,DS
      RX=XR*SCX
      RY=YR*SCX-BOUND
      IF (RY.LT.0.) GO TO 100
      CALL PLOT(RX, RY, IPEN)
  100 RETURN
      END
```

```
      SUBROUTINE FRICTN
      COMMON DEP(20000),MI,MJ,SCX,SCALE,GRID,PD
      COMMON B1, B2, BOUND, CKDEP, CO, CXY, D(12), DCDH, DCON,
     1DELTAS, DRC, DTGR, DXY, E(6), GRINC,
     2H, HH, HO, ICN, IGO, IRET, ISP, JGO, KFIRST, KPLOT,
     3LIMNPT, LPLOT, NPRINT, NPT, PHX, PHY, R90, RADIUS, RAYNO,
     4RCCO, RHS, RK, SCNV, SIG, SK, SKI, T, THI, TOP,
     5V, WL, WLO, XP, XSG, XSGL, YP, YSG, YSGL
      COMMON HPREV,SKPREV,RKPREV,UBOT,UMID,ET,CGR,POW,PL,DS
      DX=DS*GRID
      OH=HPREV*(SK/SKPREV)*(RK/RKPREV)
      PI=3.14159265
      G=32.17
      ARG=2.*PI*DXY/WL
      PHI=.6391*((SK/SINH(ARG))**3)
      HNEW=OH/((.02*OH*PHI*DX)/(SK*T**4)+1.)
      HPREV=HNEW
C
C     H=HNEW
C
C        THE ABOVE CARD SHOULD BE USED IF THE FRICTIONAL AFFECT
C        ON WAVE HEIGHT IS DESIRED
C
      UBOT=H*G/(2.*CXY*COSH(ARG))
      UMID=UBOT*COSH(ARG*.5)
      RETURN
      END
```

```
      SUBROUTINE ENERGY(A,END)
      COMMON DEP(20000),MI,MJ,SCX,SCALF,GRID,PD
      COMMON B1, B2, BOUND, CKDEP, CO, CXY, D(12), DCDH, DCON,
     1DELTAS, DRC, DTGR, DXY, E(6), GRINC,
     2H, HH, HO, ICN, IGO, IRET, ISP, JGO, KFIRST, KPLOT,
     3LIMNPT, LPLOT, NPRINT, NPT, PHX, PHY, R90, RADIUS, RAYNO,
     4RCCO, RHS, RK, SCNV, SIG, SK, SK1, T, THI, TOP,
     5V, WL, WLO, XP, XSG, XSGL, YP, YSG, YSGL
      COMMON HPREV,SKPREV,RKPREV,UBOT,UMID,ET,CGR,POW,PL,DS
      COMMON IDIR
      DATA LEFT/'L'/,IRIGHT/'R'/
      PI=3.14159265
      IF (PHY .EQ. 0.) GO TO 20
      AA=A
      IF (AA .GT. 6.2831852) AA=A-6.2831852
      THETA=ATAN(PHX/PHY)+PI/2.
      THETA=PI-THETA
   10 DTHETA=THETA-AA
      IF (DTHETA .LT. 0.) IDIR=IRIGHT
      IF (DTHETA .GT. 0.) IDIR=LEFT
      DX=DS*GRID
      ET=8.*H*H*WL
      ATHETA=ABS(DTHETA)
      DTHETA=ATHETA
      DLR=4.*PI*DXY/WL
      SDLR=SINH(DLR)
      IF (SDLR .LT. 1.E-10) SDLR=1.E-10
      CGR=.5*CXY*(1.+DLR/SDLR)
      POW=8.*H*H*CGR
      PL=POW*SIN(ATHETA)*COS(ATHETA)
      IF (END .NE. 1.) RETURN
      HB=H
      ALPHA=DTHETA
C
C        PLS IS AN ESTIMATE OF THE LONGSHORE COMPONENT OF ENERGY FLUX &N
C        SURF ZONE. BECAUSE IN THE CALCULATION OF PLS THE SIGNIFICANT WA
C        HEIGHT IS USED INSTEAD OF THE ROOT-MEAN-SQUARE THE VALUE OF PLS
C        APPROXIMATELY TWICE THE VALUE OF THE EXACT ENERGY FLUX. THEREFC
      REAL YUMY(20000)
C        PLS IS MORE APPROPRIATELY REFERRED TO AS THE LONGSHORE ENERGY
C        FLUX FACTOR.
C
C        PLS=32.1*(HB**2.5)*SIN(2*ALPHA)
C
      PLS=32.1*(HB**2.5)*SIN(2*ALPHA)
      HBM=HB/3.281
      PLSM=(2.69*10**10)*(HBM**2.5)*SIN(2*ALPHA)
```

```
      WRITE (6,220) PLS
  220 FORMAT ('0',' LONGSHORE ENERGY FLUX FACTOR:  PLS=',E14.7,
     *  ' FT-LBS/SEC/FT OF BEACH FRONT')
C
C        APPROXIMATION OF LONGSHORE TRANSPORT RATE: (1) BASED ON PLS
C        (2) BASED ON GALVIN(1972)-ESTIMATE OF THE GROSS LONGSHORE TRAN
C        RATE.
C
      Q1=7500*PLS
      Q2=200000*HB*HB
      QM=.000128*PLSM
      WRITE (6,230) Q1,IDIR,Q2
  230 FORMAT (' ',' LONGSHORE TRANSPOPT RATES:',/,' ',11X,
     1  'FUNCTION OF PLS: Q=',E14.7,' CUBIC YARDS/YR',5X,'FACING OCEAN:
     2  TRANSPORT TO ',A1,/,' ',12X,
     3  'FUNCTION OF HB: Q=',E14.7,' CUBIC YARDS/YR',5X,'GALVIN(1972) -
     4GROSS TRANSPORT RATE')
      WRITE (6,250) PLSM, QM
  250 FORMAT ('0',' METRIC CONVERSIONS:',/,' ',11X,' PLS=',E14.7,
     *  ' ERGS/METER*SEC',/,' ',13X,' Q=',E14.7,' CUBIC METERS/YEAR')
      RETURN
C
   20 THETA=PI
      GO TO 10
      END
```

```
      SUBROUTINE BOTTOM
C
C           THIS PROGRAM CREATES A MAP WITH DEPTHS AT EQUALLY SPACED
C           DISTANCES FROM A DIGITIZED BATHYMETRIC MAP USING THE
C     CONTOURS
C
C           THIS PART OF THE PROGRAM READS THE TAPE AND CONVERTS THE
C           MENU TO CORRECT FORM FOR PROCESSING.
C
      COMMON DEPTH(20000),IXAX,IYAX,SCX,SCALE,GRID,PD
      COMMON H1, H2, BOUND
      DIMENSION A(4096)
      DIMENSION IPX(5), IPY(5)
      DIMENSION IDEPTH(100)
      DIMENSION PPD(1000)
      DIMENSION IX(20000),IY(20000)
      DATA A0,A1,A2,A3,A4,A5,A6,A7,A8,A9/'0','1','2','3','4','5','6',
     1                                  '7','8','9'/
      DATA AH,AN/'H','N'/
      DATA AST/'*'/
      DATA AL /'L'/
      DATA ASLSH,APLUS,AMINUS/'/','+','-'/
      DATA AD,AE,AF,AP,AS/'D','E','F','P','S'/
      IPPSW=0
      IPEN=0
      ILL = 0
      IXSW = 0
      IP = 0
      IX(1) = 0.0
      IY(1) = 0.0
      DDIV = 10.0
      IPSW = 0
      ISHR = 0
      IEND = 0
      IIISW = 0
      ICT = 0
      ISTOP = 1
8000  FORMAT (3A4)
      IS = 0
      IXY = 1
      II = 1
      ID = 0
      IPT = -1
      IN = 5
      IOUT = 6
      ITAPE = 17
      IDISK = 12
```

```
      ISLSH = 0
      INUMB = 0
      ISIGN = 0
      IEND = 0
      III = 0
C
C           READ INPUT TAPE FROM DIGITIZER
C
  200 READ (ITAPE,9000) (A(I),I=1,4096)
 9000 FORMAT (64(64A1))
      DO 2000 I = 1,4096
      IF (A(I).EQ.A0) GO TO 500
      IF (A(I).EQ.A1) GO TO 520
      IF (A(I).EQ.A2) GO TO 540
      IF (A(I).EQ.A3) GO TO 560
      IF (A(I).EQ.A4) GO TO 580
      IF (A(I).EQ.A5) GO TO 600
      IF (A(I).EQ.A6) GO TO 620
      IF (A(I).EQ.A7) GO TO 640
      IF (A(I).EQ.A8) GO TO 660
      IF (A(I).EQ.A9) GO TO 680
      IF (A(I).EQ.ASLSH) GO TO 940
      IF (A(I).EQ.APLUS) GO TO 980
      IF (A(I).EQ.AMINUS) GO TO 1010
      IF (A(I).EQ.AD) GO TO 1040
      IF (A(I).EQ.AE) GO TO 1080
      IF (A(I).EQ.AF) GO TO 4500
      IF (A(I).EQ.AS) GO TO 1080
      IF (A(I).EQ.AP) GO TO 1140
      IF (A(I).EQ.AL) GO TO 1135
      IF (A(I).EQ.AH) GO TO 4300
      IF (A(I).EQ.AN) GO TO 4200
      IF (A(I).EQ.AST) GO TO 4230
      GO TO 2000
  500 INUMB = INUMB * 10
      GO TO 690
  520 INUMB = INUMB * 10 + 1
      GO TO 690
  540 INUMB = INUMB * 10 + 2
      GO TO 690
  560 INUMB = INUMB * 10 + 3
      GO TO 690
  580 INUMB = INUMB * 10 + 4
      GO TO 690
  600 INUMB = INUMB * 10 + 5
      GO TO 690
  620 INUMB = INUMB * 10 + 6
      GO TO 690
  640 INUMB = INUMB * 10 + 7
      GO TO 690
```

```
 660 INUMB = INUMB * 10 + 8
     GO TO 690
 680 INUMB = INUMB * 10 + 9
 690 ICT = ICT + 1
     IF (IPPSW .EQ. 1) GO TO 2000
     IF (IS.EQ.1) GO TO 2000
     IF (ICT.GT.5) GO TO 1230
     IF (ICT.LT.5) GO TO 2000
     GO TO (730, 790),IXY
 730 IXY = 2
     XSS = FLOAT (INUMB) * SCALE / 1000.0
     IF (ISIGN.NE.2) GO TO 860
     XSS = - XSS
     GO TO 860
 790 IXY = 1
     YSS = FLOAT (INUMB) * SCALE / 1000.0
     IF (ISIGN.NE.2) GO TO 830
     YSS = - YSS
 830 IX (II) = XSS + 0.5
     IY (II) = YSS + 0.5
     IF (ISTOP .EQ. 1) GO TO 860
     II = II + 1
     IF (II.GT.20000) GO TO 1310
 850 CONTINUE
     IF (II .LE. 2) GO TO 851
     IIHX = IABS (IX (II - 1) - IX (II -2))
     XHII=FLOAT(IIHX)
     IF (XHII .LT. ABS(GRID+.5)) GO TO 851
     IX (II) = IX (II-1)
     IY (II) = IY (II-1)
     IX (II-1) = (IX (II) + IX (II-2)) / 2
     IY (II-1) = (IY (II) + IY (II-2)) / 2
     II = II + 1
 851 CONTINUE
     IF (IP .LE. 5) GO TO 860
     DPTH=IDEPTH(ILL)/10.0
     WRITE (11,9980) XSS,YSS,DPTH,IPEN
9980 FORMAT (4A4)
     IF (ISHP.EQ.1) GO TO 4400
     IPEN=2
 860 ISIGN = 0
     ICT = 0
     INUMB = 0
     GO TO 2000
 940 IF (ISLSH.EQ.1) GO TO 1330
     IF (ICT .LT. 5) GO TO 1220
     ISLSH = 1
     ILL = ILL + 1
     IF (ILL.GT.100) GO TO 1380
     IF (ISIGN .EQ. 2) INUMB = -INUMB
```

```
      IDEPTH (ILL) = INUMB
      IS = 0
      ID = 0
      GO TO 860
  980 IF (ISIGN.NE.0) GO TO 1350
      ISIGN = 1
      GO TO 2000
 1010 IF (ISIGN.NE.0) GO TO 1350
      ISIGN = 2
      GO TO 2000
 1040 IF (ID.EQ.1) GO TO 1370
      ISLSH = 0
      IS = 1
      IPEN=3
      IP = 1
      ISTOP = 0
      GO TO 860
 1080 ISTOP = 1
      ISHR = 0
      IF (IP.GT.5) GO TO 4100
      IF (IPSW.EQ.0) GO TO 1090
      IF (IPT.GE.1) GO TO 1170
 1090 IXY = 1
      II = II + 1
      ISLSH = 0
      IPSW = 0
      GO TO 860
 1135 ILL = ILL + 1
      IDEPTH (ILL) = IHDPTH
      IX (II) = 0.0
      IY (II) = 0.0
 1140 IPSW = 1
 1150 IPT = IPT + 1
      IP = IP + 1
      IPX(IP) = IX(II)
      IPY(IP) = IY(II)
      GO TO 860
 1170 IF (IPT.GT.1) GO TO 3010
C
C     X -AXI   BOTTOM
C
      IHDPTH = IDEPTH (1)
      NNN = 0
      IXDIS = IX(II) - IX(1)
      IYDIS = IY(II) - IY(1)
      XDIS = FLOAT (IXDIS)
      YDIS = FLOAT (IYDIS)
      XDIS = ABS(XDIS)
      YDIS = ABS(YDIS)
      IF (XDIS.EQ.0.0) XDIS = 0.0001
```

```
      THETA1 = ATAN(YDIS/XDIS)
      DIS = SQRT (XDIS**2 + YDIS**2)
      DIS1 = DIS
      ALEFT = 0.0
C
C     CALCULATE LENGTH OF INCREMENTS ALONG X - BOTTOM
C
      AXD = DIS / FLOAT (IXAX - 1)
      II = II - 1
      DO 3000 LM = 1,II
      IXX = IABS(IX(LM) - IX(LM+1))
      IYY = IABS(IY(LM) - IY(LM+1))
      XX = IXX
      YY = IYY
C
C     CALCULATE DISTANCE TO NEXT POINT
C
      DD = SQRT (XX ** 2 + YY **2)
      IDC= IDEPTH(LM+1) - IDEPTH(LM)
      ADC = FLOAT (IDC) / DDIV
      DPH = FLOAT (IDEPTH (LM)) / DDIV
      DPH2 = FLOAT (IDEPTH (LM+1)) / DDIV
      IF (ALEFT .GT. DD) GO TO 2990
      IF (ALEFT.LE.0.0) GO TO 2900
      NNN = NNN + 1
      DEPTH (NNN) = DPH + ALEFT * ADC / DD
      DPH = DEPTH (NNN)
      DD = DD - ALEFT
 2900 AN = DD/AXD
      AIDC = (DPH2 - DPH) / AN
      NN = AN
      IF (NN.EQ.0) GO TO 2960
C
C     CALCULATE DEPTH INCREMENTS
C
      DO 2950 LN = 1,NN
      NNN = NNN + 1
      DEPTH (NNN) = DPH + FLOAT (LN) * AIDC
 2950 CONTINUE
 2960 CONTINUE
      ALEFT = DD - FLOAT(NN) * AXD
      ALEFT = AXD - ALEFT
      GO TO 3000
 2990 ALEFT = ALEFT - DD
 3000 CONTINUE
      II = II + 1
      IF (IY(1).LT.IY(II)) GO TO 3003
      IY(1) = IY(II)
      GO TO 3004
 3003 IY(II) = IY(1)
```

```
 3004 CONTINUE
      IB = IXAX - 1
      DO 3005 J = 1,IB
      PPD (J+1) = DEPTH(J)
 3005 CONTINUE
      MMM = IB + 1
      IX(1) = IX(II)
      IY(1) = IY(II)
      II = 1
      IDEPTH (1) = IDEPTH (ILL)
      ILL = 1
      GO TO 1090
 3010 IF (IPT.GT.2) GO TO 3410
      ALEFT = 0.0
C
C     Y-AXIS - FAR SIDE
C
      NNN = 0
      IXDIS = IX(II) - IX(1)
      IYDIS = IY(II) - IY(1)
      XDIS = FLOAT (IXDIS)
      YDIS = FLOAT (IYDIS)
      XDIS = ABS(XDIS)
      YDIS = ABS(YDIS)
      IF (XDIS.EQ.0.0) XDIS = 0.0001
      THETA2 = ATAN (YDIS/XDIS)
      DIS = SQRT (XDIS ** 2 + YDIS **2)
      DIS2 = DIS
C
C     CALCULATE LENGTH OF INCREMENTS ALONG Y - RIGHT SIDE
C
      AYD = DIS / FLOAT (IYAX - 1)
      II = II - 1
      DO 3360 LM = 1,II
      IXX = IABS (IX(LM) - IX(LM+1))
      IYY = IABS (IY(LM) - IY(LM+1))
      XX = IXX
      YY = IYY
      DD = SQRT (XX ** 2 + YY ** 2)
      IDC = IDEPTH(LM + 1) - IDEPTH(LM)
      ADC = FLOAT (IDC) / DDIV
      DPH = FLOAT (IDEPTH (LM)) / DDIV
      DPH2 = FLOAT (IDEPTH (LM+1)) / DDIV
      IF (ALEFT .GT. DD) GO TO 3350
      IF (ALEFT.LE.0.0) GO TO 3270
      NNN = NNN + 1
      DEPTH (NNN) = DPH + ALEFT * ADC / DD
      DPH = DEPTH (NNN)
      DD = DD - ALEFT
 3270 AN = DD/ AYD
```

```
      AIDC = (DPH2 - DPH) / AN
      NN = AN
      IF (NN.EQ.0) GO TO 3330
      DO 3320 LN = 1,NN
      NNN = NNN + 1
      DEPTH (NNN) = DPH + FLOAT (LN) * AIDC
 3320 CONTINUE
 3330 CONTINUE
      ALEFT = DD - FLOAT(NN) * AYD
      ALEFT = AYD - ALEFT
      GO TO 3360
 3350 ALEFT = ALEFT - DD
 3360 CONTINUE
      II = II + 1
      IF (IX(1).GT.IX(II)) GO TO 3365
      IX(1) = IX(II)
      GO TO 3367
 3365 IX(II) = IX(1)
 3367 CONTINUE
      MMMM = MMM + IYAX - 2
      DO 3370 J = MMM,MMMM
      JJJ = J - MMM + 1
      PPD (J+1) = DEPTH (JJJ)
 3370 CONTINUE
      MMM = MMMM + 1
      IX(1) = IX(II)
      IY(1) = IY(II)
      II = 1
      IDEPTH (1) = IDEPTH (ILL)
      ILL = 1
      GO TO 1090
 3410 IF (IPT.GT.3) GO TO 3780
C
C     X-AXIS - BACK
C
      NNN = 0
      IXDIS = IABS(IX(II) - IX(1))
      IYDIS = IABS(IY(II) - IY(1))
      ALEFT = 0.0
      XDIS = FLOAT (IXDIS)
      YDIS = FLOAT (IYDIS)
      IF (XDIS.EQ.0.0) XDIS = 0.0001
      THETA3 = ATAN (YDIS/XDIS)
      DIS = SQRT (XDIS ** 2 + YDIS ** 2)
      DIS3 = DIS
C
C     CALCULATE LENGTH OF INCREMENTS ALONG X - TOP
C
      AXD = DIS / FLOAT (IXAX - 1)
      II = II - 1
```

```
      DO 3730 LM = 1,II
      IXX = IABS (IX(LM) - IX(LM+1))
      IYY = IABS (IY(LM) - IY(LM+1))
      XX = IXX
      YY = IYY
      DD = SQRT (XX ** 2 + YY ** 2)
      IDC = IDEPTH(LM+1) - IDEPTH(LM)
      ADC = FLOAT (IDC) / DDIV
      DPH = FLOAT (IDEPTH (LM)) / DDIV
      DPH2 = FLOAT (IDEPTH (LM+1)) / DDIV
      IF (ALEFT .GT. DD) GO TO 3720
      IF (ALEFT.LE.0.0) GO TO 3650
      NNN = NNN + 1
      DEPTH (NNN) = DPH + ALEFT * ADC / DD
      DPH = DEPTH (NNN)
      DD = DD - ALEFT
 3650 AN = DD / AXD
      AIDC = (DPH2 - DPH) / AN
      NN = AN
      IF (NN.EQ.0) GO TO 3710
      DO 3700 LN = 1,NN
      NNN = NNN + 1
      DEPTH (NNN) = DPH + FLOAT (LN) * AIDC
 3700 CONTINUE
 3710 CONTINUE
      ALEFT = DD - FLOAT(NN) * AXD
      ALEFT = AXD - ALEFT
      GO TO 3730
 3720 ALEFT = ALEFT - DD
 3730 CONTINUE
      II = II + 1
      IF (IY(1).GT.IY(II)) GO TO 3735
      IY(1) = IY(II)
      GO TO 3737
 3735 IY(II) = IY(1)
 3737 CONTINUE
      MMMM = MMM + IXAX - 2
      DO 3740 J = MMM,MMMM
      JJJ = J - MMM + 1
      PPD (J+1) = DEPTH (JJJ)
 3740 CONTINUE
      MMM = MMMM + 1
      IX(1) = IX(II)
      IY(1) = IY(II)
      II = 1
      IDEPTH (1) = IDEPTH (ILL)
      ILL = 1
      GO TO 1090
 3780 IF (IPT.NE.4) GO TO 4020
C
```

```
C       Y-AXIS DOWN
C
        NNN = 0
        IXDIS = IABS(IX(II) - IX(1))
        IYDIS = IABS(IY(II) - IY(1))
        XDIS = FLOAT (IXDIS)
        YDIS = FLOAT (IYDIS)
        IF (XDIS.EQ.0.0) XDIS = 0.0001
        THETA4 = ATAN (YDIS/XDIS)
        DIS = SQRT (XDIS ** 2 + YDIS ** 2)
        DIS4 = DIS
        AYD = DIS / FLOAT (IYAX - 1)
        II = II - 1
        ALEFT = 0.0
        DO 3990 LM = 1,II
        IXX = IABS (IX(LM) - IX(LM+1))
        IYY = IABS (IY(LM) - IY(LM+1))
        XX = IXX
        YY = IYY
        DD = SQRT (XX ** 2 + YY ** 2)
        IDC = IDEPTH(LM+1) - IDEPTH(LM)
        ADC = FLOAT (IDC) / DDIV
        DPH = FLOAT (IDEPTH (LM)) / DDIV
        DPH2 = FLOAT (IDEPTH (LM+1)) / DDIV
        IF (ALEFT .GT. DD) GO TO 3980
        IF (ALEFT.LE.0.0) GO TO 3910
        NNN = NNN + 1
        DEPTH (NNN) = DPH + ALEFT * ADC / DD
        DPH = DEPTH (NNN)
        DD = DD - ALEFT
 3910   AN = DD / AYD
        AIDC = (DPH2 - DPH) / AN
        NN = AN
        IF (NN.EQ.0) GO TO 3970
        DO 3960 LN = 1,NN
        NNN = NNN + 1
        DEPTH (NNN) = DPH + FLOAT (LN) * AIDC
 3960   CONTINUE
 3970   CONTINUE
        ALEFT = DD - FLOAT (NN) * AYD
        ALEFT = AYD - ALEFT
        GO TO 3990
 3980   ALEFT = ALEFT - DD
 3990   CONTINUE
        IP=6
        IX(1) = 0
        IX(II) = 0
        MMMM = MMM + IYAX - 3
        DO 4000 J = MMM,MMMM
        JJJ = J - MMM + 1
```

```
      PPD (J+1) = DEPTH (JJJ)
      PI = 3.141593
 4000 CONTINUE
      PPD (1) = DEPTH(MMMM - MMM + 2)
      II = 0
      THETA1 = THETA1 * PI / 180.0
      THETA2 = THETA2 * PI / 180.0
      THETA3 = THETA3 * PI / 180.0
      THETA4 = THETA4 * PI / 180.0
C
C     FIND INCREMENTS ON X-AXIS - BOTTOM
C
      ANC1 = DIS1 / FLOAT (IXAX - 1)
C
C     FIND INCREMENTS ON X-AXIS - TOP
C
      ANC2 = DIS3 / FLOAT (IXAX - 1)
      ANCAV = (DIS1 + DIS3) / 2.0
      ANCAV = ANCAV / FLOAT (IXAX - 1)
      ILL = 0
      GO TO 1090
 4020 WRITE (6,6030)
 6030 FORMAT ('1 L ENTERED EARLY')
      STOP
 4100 II = II - 1
      IF (II .LE. 1) GO TO 1090
      IXD = 99999999
      DPTH = 0.0
      IYH = 0
      IXH = 0
      IISW = 0
      MMM = 0
      XVAL = FLOAT (IX (1)) / ANCAV
      IXVAL = IFIX (XVAL + 0.5)
      XLEN = FLOAT (IXVAL) * ANCAV
      IXH = XLEN
      IYH = IY (1)
      DPTH = IDEPTH (ILL) / 10.0
      WRITE (IDISK, 8000) IXH, IYH, DPTH
      DO 4190 J = 2,II
 4110 JL = J - 1
      IF ((IX(J).EQ.IX(JL)).AND.(IY(J).EQ.IY(JL))) GO TO 4190
C
C     CALCULATE THE RANGE
      XVAL = FLOAT (IX(J)) / ANCAV
C
      IXVAL = IFIX (XVAL + 0.5)
      XLEN = FLOAT (IXVAL) * ANCAV
      IF (IISW.EQ.1) GO TO 4150
 4120 IXB1= IFIX (XLEN + 0.5 * ANCAV + 0.5)
```

```
      IXB2= IFIX (XLEN - 0.5 * ANCAV + 0.5)
      IXXAV = XLEN
 4150 IF((IX(J).GT.IXB1).OR.(IX(J).LT.IXB2)) GO TO 4180
      IIXD = IABS (IXXAV - IX(J))
      IF (IIXD.GE.IXD) GO TO 4190
      IXD = IIXD
      IXH = IXXAV
      IYH = IY(J)
      IISW = 1
      DPTH = IDEPTH (ILL) / 10.0
      GO TO 4190
 4180 IF (IISW.EQ.0) GO TO 4190
      IISW = 0
      WRITE (IDISK,8000) IXH,IYH,DPTH
      IXD = 99999999
      GO TO 4120
 4190 CONTINUE
      ILL = 0
      II = 0
      GO TO 1090
C
C     SET PEN SWITCH
C
 4200 IPPSW=1
      GO TO 860
 4230 IPPSW=0
      IPEN=INUMB
      IF (INUMB.LT.1) GO TO 4280
      IF (INUMB.GT.3) GO TO 4280
      GO TO 860
 4280 WRITE (IOUT,9020) INUMB
 9020 FORMAT ('1  PEN VALUE LT 1 OR GT 3 (',I3,')')
      STOP
 4300 ISHP = 1
      GO TO 1040
 4400 WRITE (10,9990) XSS,YSS,IPEN
 9990 FORMAT (3A4)
      IPEN=2
      GO TO 860
 4500 REWIND 12
      REWIND 10
      REWIND 17
      CALL SORT1
C
C     NOW PUT PERIMETER ON
C
      III = IXAX * IYAX
      DO 4220 K = 1,III
      DEPTH (K) = 9999.9
 4220 CONTINUE
```

```
      DO 4250 K = 1,IXAX
      DEPTH (K) = PPD (K)
 4250 CONTINUE
      IN1 = IXAX + 1
      IN = IYAX - 2
      IP = IXAX + 1
      IP1 = 2 * IXAX + 2 * IYAX - 4
      DO 4320 K = 1,IN
      IN2 = IN1 + IXAX - 1
      DEPTH (IN1) = PPD (IP1)
      DEPTH (IN2) = PPD (IP)
      IN1 = IN1 + IXAX
      IP = IP + 1
      IP1 = IP1 - 1
 4320 CONTINUE
      IN1 = (IYAX - 1) * IXAX + 1
      IP = 2 * IXAX + IYAX - 2
      DO 4390 K = 1.IXAX
      DEPTH (IN1) = PPD (IP)
      IP = IP - 1
      IN1 = IN1 + 1
 4390 CONTINUE
C
C     NOW START FILLING IN THE POINTS
C
      IDIS = 0
      NSEG = 0
      IP = 2
      IPT = 2
      ISP = IXAX
 4550 CONTINUE
      READ (13,8000) IXH,IYH,DPTH
      IF (IXH .EQ. 0) GO TO 4550
 4560 CONTINUE
      ALEFT = 0.0
      ODPTH = DEPTH (IPT)
      AYDIS = (DIS2 + DIS4) / 2.0
      AYNC = AYDIS / FLOAT (IYAX - 1)
      ISTY = 0
      IXSW = 0
 4580 CONTINUE
C
C     CALCULATE # OF SEGMENTS
C
      INC = IABS(IYH - ISTY)
      DD = FLOAT (INC)
      CHGD = DPTH - ODPTH
      IF (ALEFT.LE.0.0) GO TO 4565
      DD = DD - ALEFT
      IF (DD.LT.0.0) GO TO 4670
```

```
      NEWPT = IPT + ISP
      DEPTH (NEWPT) = ODPTH + ALEFT * CHGD / FLOAT(INC)
      ODPTH = DEPTH (NEWPT)
      IPT = IPT + IXAX
 4585 CONTINUE
      IF (DD.EQ.0.0) GO TO 4675
      AN = DD / AYNC
      NSEG = AN
      AIDC = (DPTH - ODPTH) / AN
      IF (NSEG.LE.0) GO TO 4601
      DO 4600 LMN = 1,NSEG
      NEWPT = IPT + ISP
      DEPTH (NEWPT) = ODPTH + AIDC * FLOAT(LMN)
      IPT = IPT + IXAX
 4600 CONTINUE
 4601 CONTINUE
      ALEFT = DD - FLOAT(NSEG)* AYNC
      ALEFT = AYNC- ALEFT
 4602 CONTINUE
      ODPTH = DPTH
      READ (13,6000,END=4570) IXA,IYA,DPTH
      IF (IXA .GE. IPX (2) .OR. IXA .GE. IPX (3)) GO TO 4570
      IF (IXA.EQ.IXH) GO TO 4660
 4605 ISTY = AYDIS + 0.5
      IPPT = IXAX * (IYAX - 1) + IP
      CHGD = DEPTH (IPPT) - ODPTH
      INC = IABS (IYH - ISTY)
      DD = FLOAT (INC)
      IF (ALEFT.LE.0.0) GO TO 4606
      DD = DD - ALEFT
      IF (DD.LT.0.0) GO TO 4590
      NEWPT = IPT + ISP
      DEPTH (NEWPT) = ODPTH + ALEFT * CHGD / FLOAT (INC)
      ODPTH= DEPTH (NEWPT)
      CHGD = DEPTH (IPPT) - ODPTH
      IPT = IPT + IXAX
 4606 CONTINUE
      IF (DD.EQ.0.0) GO TO 4590
      AN = DD / AYNC
      AIDC = CHGD / AN
      NSEG = AN - 1.0 + 0.5
      IF (NSEG.LE.0) GO TO 4590
      DO 4650 LMN = 1,NSEG
      NEWPT = IPT + ISP
      DEPTH(NEWPT) = ODPTH + AIDC * FLOAT (LMN)
      IPT = IPT + IXAX
 4650 CONTINUE
 4590 CONTINUE
      IF (IEND.EQ.1) GO TO 4690
      IP = IP + 1
```

```
      IPT = IP
      IXH = IXA
      IYH = IYA
      GO TO 4560
 4570 IEND = 1
      GO TO 4605
 4660 IXH = IXA
      ISTY = IYH
      IYH = IYA
      GO TO 4580
 4670 ALEFT =ABS(DD)
      GO TO 4602
 4675 ALEFT = 0.0
      GO TO 4602
 4690 IIAX = 1
      IIIAX = IXAX
      ITOT=IYAX*IXAX
      DO 100 K=1,ITOT
      IF (DEPTH(K) .EQ. 9999.90) DEPTH(K)=DEPTH(K-1)
  100 CONTINUE
      DO 4695 K = 1,IYAX
      WRITE (8,6040) K,(DEPTH(II),II=IIAX,IIIAX)
      IIAX = IIAX + IXAX
      IIIAX = IIIAX + IXAX
 6040 FORMAT (' ',I10,(12F10.2),/)
 4695 CONTINUE
      RETURN
C
C     NOW WRITE AXIS VALUE TO DISK FILE
C
 1220 WRITE(IOUT,6001)
 6001 FORMAT('1 NUMBER TOO SHORT',//)
 1230 WRITE (IOUT,6000)
 6000 FORMAT ('1 NUMBER TOO LONG',//)
 1240 J = I - 20
      IF (J.LT.1) J = 1
      J2 = J + 40
      IF (J2.LE.4096) GO TO 1290
      J = J2 - 40
 1290 WRITE (IOUT,6005) (A(KK),KK=J,J2)
 6005 FORMAT (' ',41A1)
      STOP
 1310 WRITE (IOUT,6010)
 6010 FORMAT ('1  EXCEEDED 20000 POINTS ON ONE CONTOUR')
      STOP
 1330 WRITE (IOUT,6015)
 6015 FORMAT ('1  NO DEPTH BETWEEN SLASHES')
      STOP
 1350 WRITE (IOUT,6020)
 6020 FORMAT ('1 TWO SIGNS WITH ONE NUMBER')
```

```
      GO TO 1240
 1370 WRITE (IOUT,6025)
 6025 FORMAT ('1  NO SLASH BETWEEN DEPTHS')
      IOFF = 0
      STOP
 1380 WRITE (IOUT,6035)
 6035 FORMAT ('1 MORE THAN 100 DEPTHS ALONG AN AXIS')
      STOP
 2000 CONTINUE
      GO TO 200
      END
```

```
/*
// EXEC ASMGCL,PARM.LKED='LET.LIST,XREF,CALL'
//ASM.SYSLIN DD UNIT=,SPACE=
//ASM.SYSIN DD *
SORT1    CSECT
BEGIN    SAVE  (14,12)
         BALR  11,0
         USING *,11
         LR    12,13
         LA    13,SAVEA
         ST    13,8(12)
         ST    12,4(13)
         B     HERE
SAVEA    DS    18F
HERE     LA    1,PARLIST
         LINK  EP=SORT,MF=(E,(1))
         L     13,SAVEA+4
         RETURN (14,12)
         CNOP  0,8
PARLIST  DC    X'80'
         DC    AL3(ADLIST)
         DC    X'0000'
ADLIST   DC    X'0024'
         DC    A(SORTCD)
         DC    A(STCDED)
         DC    A(RCDCD)
         DC    A(RDCDED)
         DC    F'0'
         DC    F'0'
         DC    X'0000'
         DC    X'6590'
         DC    C'BALN'
         DC    X'FF00'
         DC    C'AC'
SORTCD   DC    C' SORT FIELDS=(1,4,A,5,4,A),FORMAT=FI'
STCDED   DC    C' '
RCDCD    DC    C' RECORD LENGTH=12,TYPE=F'
RDCDED   DC    C' '
         END
/*
//LKED.SYSLMOD DD DSN=N310013.WORK(REFRAC),DISP=(NEW,CATLG),
//     SPACE=(TRK,(10,2,28),RLSE),DCB=LOADMOD,
//      UNIT=3330V,MSVGP=USCQ
//LKED.SYSLIB DD DSN=SYS1.FORTLIB,DISP=SHR
//              DD DSN=SM1.LINKLIB,DISP=SHR
//  DD DSN=ACAD.SUBLIB.G5005,DISP=SHR,UNIT=,VOL=SER=
//
```

TAPE TO DISK (TTD)

The program TTD is an Assembler routine that copies the digitized depth data from magnetic tape to disk. A listing of the JCL and source deck follows this brief description of how to use the program.

The //GO.INTAPE card specifies the tape volume to be stored. The ????? in the VOL=SER=????? parameter is replaced by the number on the tape reel. For example, if the number were CRD26, the parameter will be VOLUME=SER=CRD26.

The //GO.OUTTAPE specifies the output data set name, under which the depth data is to be stored. See JCL Considerations for rules on coding the data set names (DSN).

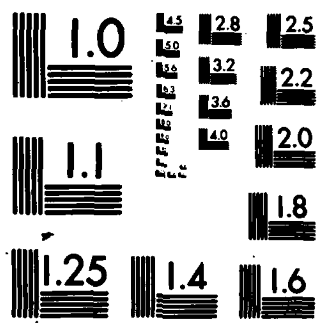
LISTING OF TTD (TAPE TO DISK)

```
//TTD JOB N3100138,TTD,TIME=(,9),
//  USER=N310013,PASSWORD=CRD
//STP1 EXEC ASMFCLG
//ASM.SYSIN DD *
COPY     START 0
R15      EQU   15
R14      EQU   14
R13      EQU   13
R12      EQU   12
R11      EQU   11
R3       EQU   3
R4       EQU   4
BEGIN    STM   R14,R12,12(R13)
         LR    R12,R15
         USING BEGIN,R12
         B     ARD
SAVEA    DS    18F
ARD      LA    R11,SAVEA
         ST    R11,8(R13)
         ST    R13,4(R11)
         LR    R13,R11
         L     R11,=A(TAPEIN-1024)
         USING TAPEIN-1024,R11
         OPEN  (TAPEIN,INPUT,TAPEOUT,OUTPUT)
LOOP     EQU   *
         GET   TAPEIN,RECORD
         PUT   TAPEOUT,RECORD
         L     R3,=F'4096'
         LA    R4,RECORD
LOOP1    EQU   *
         CLI   0(R4),C'F'
         BE    EOF
         LA    R4,1(R4)
         BCT   R3,LOOP1
         B     LOOP
EOF      EQU   *
         PUT   TAPEOUT,RECORD
         CLOSE (TAPEIN,,TAPEOUT)
         L     R13,4(R13)
         LM    R14,R12,12(R13)
         BR    R14
         LTORG
RECORD   DS    4096C
TAPEIN   DCB   DSORG=PS,MACRF=GM,DDNAME=INTAPE,LRECL=4096,BLKSIZE=4096,X
               RECFM=F,EODAD=EOF,BUFNO=1
TAPEOUT  DCB   DSORG=PS,MACRF=PM,DDNAME=OUTTAPE,LRECL=4096,            X
```

```
                 BLKSIZE=4096,RECFM=F
            END   BEGIN
/*
//GO.SYSUDUMP  DD  SYSOUT=A
//GO.INTAPE  DD  DSN=SJC,UNIT=TAPED,DISP=OLD,VOLUME=SER=?????,
//        DCB=(BLKSIZE=4096,RECFM=F,EROPT=ACC,BUFNO=1),LABEL=(1,BLP)
//GO.OUTTAPE DD DSN=N310013.EXAMPLE,DISP=(NEW,CATLG,DELETE),
//    UNIT=3330V,MSVGP=USCP,SPACE=(TRK,(5,2),RLSE),
//    DCB=(BLKSIZE=4096,RECFM=F)
/*
//
```

AD-A091 913 SOUTH CAROLINA UNIV COLUMBIA COASTAL RESEARCH DIV F/G 8/3
INFLUENCE OF WAVE REFRACTION ON COASTAL GEOMORPHOLOGY-BULL ISLA--ETC(U)
DEC 78 C FICO DAAG29-76-G-0111
UNCLASSIFIED TR-17-CRD ARO-13237.15-GS NL

END
DATE
FILMED
81-2
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

LISTING DIGITIZED DATA (DIGCOPY)

A listing of the digitized depth information can be printed from disk by the Assember program DIGCOPY. This is an easy means of verifying the digitized data by comparing the printed X,Y coordinates and the corresponding depths with the depths on the hydrographic chart.

The data set name referred to in the //GO.TAPE card (third from the last card) is the same data set name used in the //GO.OUTTAPE card in the TTD program previously described. (This program, DIGCOPY, and TTD were written by Jim Crabtree to aid in transferring data and in error checking.)

LISTING OF DIGCOPY (DIGITIZED TAPE)

```
//DIGCOPY JOB (N310013A,9),DIGCOPY,TIME=(,9),MSGLEVEL=(1,1),
//  USER=N310013,PASSWORD=CRD
//STEP1  EXEC  ASMFCLG
//ASM.SYSIN  DD  *
         PRINT NOGEN
DISPLAY  START 0
R0       EQU   0
R1       EQU   1
R2       EQU   2
R3       EQU   3
R4       EQU   4
R5       EQU   5
R6       EQU   6
R7       EQU   7
R8       EQU   8
R9       EQU   9
R10      EQU   10
R11      EQU   11
R12      EQU   12
R13      EQU   13
R14      EQU   14
R15      EQU   15
BEGIN    STM   R14,R12,12(R13)
         LR    R12,R15
         USING BEGIN,R12,R11
         L     R11,BASE2
         B     ARD
ASAVE    DS    18F
BASE2    DC    A(BEGIN+4096)
ARD      EQU   *
         LA    R10,ASAVE
         ST    R10,8(R13)
         ST    R13,ASAVE+4
         LR    R13,R10
         LA    R7,1
         OPEN  (TAPEIN,INPUT,PRINTER,OUTPUT)
         SR    R3,R3
         LA    R5,LINE+10
         BAL   R10,HEADER
LOOP     EQU   *
*
*              GET TAPE RECORD
*
         GET   TAPEIN,TAPE
         LA    R9,TAPE
*
```

```
*                START SCAN
*
         LA      R8,4095
         LA      R8,1(R8)
ALOOP    EQU     *
         CLI     0(R9),C'0'              * NUMBER TEST
         BL      NOTNUM
         CLI     0(R9),C'9'
         BH      NOTNUM
*
*
*
         TM      EX,X'FF'
         BO      ARD2
         B       ARD1
*
*                TEST FOR ALPHA
*
NOTNUM   EQU     *
         CLI     0(R9),C'Z'
         BH      SPECERR
         CLI     0(R9),C'S'
         BL      SPEC
         B       ALPHA
SPEC     EQU     *
         CLI     0(R9),C'R'
         BH      SPECERR
         CLI     0(R9),C'J'
         BL      SPEC1
         B       ALPHA
SPEC1    EQU     *
         CLI     0(R9),C'A'
         BL      SPEC2
         CLI     0(R9),C'I'
         BH      SPECERR
         B       ALPHA
*
*                TEST FOR SPECIAL CHARACTERS
*
SPEC2    EQU     *
         CLI     0(R9),C'/'              * SLASH
         BE      ALPHA
         CLI     0(R9),C'-'              * MINUS
         BE      MOVEXY
         CLI     0(R9),C'*'              * ASTERICK
         BE      ALPHA
         CLI     0(R9),C'+'              * PLUS
         BE      MOVEXY
         CLI     0(R9),C'.'
         BE      ARD2
```

```
         B       SPECERR
MOVEXY   EQU     *
         MVI     EX,X'00'
         TM      ALP,X'FF'
         BZ      MOVEXY1
         C       R5,=A(LINE+10)
         BE      MOVEXY1
         LA      R3,1(R3)
         BAL     R6,WRITER
MOVEXY1  EQU     *
         MVI     ALP,X'00'
         CLI     XY,C'X'                       * X VALUE
         BNE     Y                             * NO
         LA      R3,1(R3)
         MVI     XY,C'Y'
         LA      R4,LINE+130                   * ENOUGH SPACE LEFT ?
         SR      R4,R5
         C       R4,=F'12'
         BH      ARD2
         BCTR    R3,0
         BAL     R6,WRITER
         LA      R3,1(R3)
         B       ARD2
ARD1     EQU     *
         TM      ALP,X'FF'
         BZ      ARD2
         LA      R3,1(R3)
         MVI     EX,X'FF'
ARD2     EQU     *
         MVC     0(1,R5),0(R9)
         LA      R5,1(R5)
         LA      R9,1(R9)
         B       TEST
Y        EQU     *
         MVI     XY,C'X'
         B       ARD2
ALPHA    EQU     *
         MVI     EX,X'00'
         MVI     ALP,X'FF'
         C       R5,=A(LINE+10)
         BE      ALPHA1
         BAL     R6,WRITER
ALPHA1   EQU     *
         LA      R3,1(R3)
         MVC     0(1,R5),0(R9)
         BAL     R6,WRITER
         CLI     0(R9),C'F'                    * END TEST
         BE      CLOSE
         LA      R9,1(R9)
         MVI     XY,C'X'
```

```
TEST     EQU   *
         C     R5,=A(LINE+130)          * LINE EXCEEDED
         BL    TEST1                    * NO
         BAL   R6,WRITER                * YES
TEST1    EQU   *
         BCT   R8,ALOOP
         MVI   XY,C'X'
         B     LOOP
HEADER   EQU   *
         MVI   PLINE,C'1'
         MVI   LINE,C' '
         MVC   LINE+1(131),LINE
         MVC   LINE+10(26),=CL26'CHARACTER DISPLAY OF TAPE'
         MVC   LINE+100(4),=CL4'PAGE'
         MVC   LINE+104(4),=XL4'40202120'
         ED    LINE+104(4),PAGECT
         AP    PAGECT,=P'1'
         PUT   PRINTER,PLINE
         MVI   PLINE,C' '
         MVC   LINE(132),PLINE
         MVC   LINE(116),HEAD
         PUT   PRINTER,PLINE
         ZAP   LINECT,=P'3'
         MVI   PLINE,C'0'
         MVI   LINE,C' '
         MVC   LINE+1(131),LINE
         BR    R10
SPECERR  EQU   *                        * UNSPECIFIED CHARACTER
         CLI   0(R9),X'00'              * BLOCK FILLER
         BE    TEST1
         BAL   R6,WRITER
         MVC   LINE(5),=CL5'*****'      * UNIDENTIFIED CHARACTER
         BAL   R6,WRITER
         TRT   0(1,R9),TAB1
         BZ    ALPHA
         MVC   BYTES(2),=XL2'0000'
         MVZ   BYTE1,0(R9)
         MVN   BYTE2,0(R9)
         PACK  BYTE1,BYTE1
         TR    BYTES(2),TAB2
         MVC   LINE+10(2),BYTES
         MVC   LINE+14(31),=CL31'(UNIDENTIFIED CHARACTER IN HEX)'
         BAL   R6,WRITER
         LA    R9,1(R9)
         B     TEST1
WRITER   EQU   *
         CLC   LINE(5),=CL5'*****'
         BE    W1
         MVC   LINE(8),=XL8'4020202020202120'
         CVD   R7,DOUB
```

```
         ED    LINE(8),DOUB+4
         AR    R7,R3
W1       EQU   *
         PUT   PRINTER,PLINE
         MVI   PLINE,C' '
         MVC   LINE(132),PLINE
         AP    LINECT,=P'1'
         CP    LINECT,=P'60'
         BL    WRITER1
         BAL   R10,HEADER
WRITER1  EQU   *
         LA    R5,LINE+10
         SR    R3,R3
         BR    R6
CLOSE    EQU   *
         CLOSE (TAPEIN,,PRINTER)
         L     R13,ASAVE+4
         LM    R14,R12,12(R13)
         BR    R14
         LTORG
DOUB     DS    D
TAPE     DS    4096C
XY       DC    C'X'
PLINE    DS    C
LINE     DS    CL132
HEAD     DC    CL49'RECORD #     X     Y     X     Y     X     Y     '
         DC    CL48'X     Y     X     Y     X     Y     X     Y     '
         DC    CL19'X     Y     X     Y'
PAGECT   DC    PL2'1'
LINECT   DC    PL2'0'
BYTES    DS    0CL2
BYTE1    DC    X'00'
BYTE2    DC    X'00'
EX       DC    X'00'
ALP      DC    X'00'
TAB2     DC    CL16'0123456789ABCDEF'
TAB1     DC    256X'FF'
         ORG   TAB1+74
         DC    XL7'00000000000000'
         ORG   TAB1+90
         DC    XL8'0000000000000000'
         ORG   TAB1+107
         DC    XL5'0000000000'
         ORG   TAB1+122
         DC    XL6'000000000000'
         ORG   TAB1+193
         DC    XL9'000000000000000000'
         ORG   TAB1+209
         DC    XL9'000000000000000000'
         ORG   TAB1+226
```

```
         DC      XL8'0000000000000000'
         ORG     TAB1+240
         DC      XL10'00000000000000000000'
         ORG     TAB1+256
PRINTER  DCB     DSORG=PS,DDNAME=LINES,LRECL=133,BLKSIZE=133,RECFM=FA,
                 MACRF=PM
TAPEIN   DCB     DSORG=PS,DDNAME=TAPE,LRECL=4096,BLKSIZE=4096,RECFM=F,
                 EODAD=CLOSE,MACRF=GM
         END     BEGIN
/*
//GO.LINES  DD  SYSOUT=A
//GO.SYSUDUMP  DD  SYSOUT=A
//GO.TAPE DD DSN=N310013.EXAMPLE,DISP=SHR
/*
//
```